# MACHINE SHOP PRACTICE

BY

WILLIAM B. HARTMAN
INSTRUCTOR IN MACHINE CONSTRUCTION
CARNEGIE INSTITUTE OF TECHNOLOGY

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# PREFACE

The purpose of this book is to set forth the elementary principles of machine shop practice.

The subjects are arranged in the simplest and most logical order. The measuring tools are first illustrated and explained as to form and use. The hand and the machine cutting-tools are next described. Finally the machines, alone and in combination with the tools, are treated.

Of course not every machine known to the trade is considered but the principal machines are described and their uses are explained.

Correct methods in the handling of tools and in the operation of machines are emphasized.

Only mechanical drawings are used for illustrations because they are used exclusively by the machinist in his work. The student should, therefore, from the first learn to read and use such drawings.

All higher mathematics is excluded. The mathematical calculations are confined to the use of simple arithmetic, which should easily be comprehended by the student or apprentice old enough to learn machine shop practice.

Some data, applicable to general machine shop work and useful both to the student or apprentice and to the machinist on the job, are added in the appendix. These tables are not original but have been compiled from many sources.

The author is indebted to Professor Robert J. Peters of the Carnegie Institute of Technology for many valuable suggestions and for criticism and arrangement of the final copy, and to Mr. Warren A. Emery for assistance in the preparation of the drawings.

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# MACHINE SHOP PRACTICE

## CHAPTER I

### INTRODUCTION

**Importance of the Machinist's Trade.**—The machinist's trade will always be in demand because in every line of work there is a constant effort to lessen the labor of manufacturing articles, thereby cheapening their cost. This is always done by new inventions and improved machinery. The machinist is called upon to invent, improve, and make this machinery. Again, the machinist is constantly making improvements in his own machinery and methods of doing work, and it seems as if his vocation will last forever.

No attempt will be made to cover all the different kinds of work of the machinist, but the elementary principles of the trade will be simply and correctly explained.

### MACHINIST'S MEASURING TOOLS AND THEIR USES

The principal measuring and gauging tools used by the machinist are as follows:

**Rules.**—The steel rule, Fig, 1, is an instrument for measuring short lengths. This rule can be obtained in the following lengths: 1, 2, 3, 4, 6, 9, 12, 18, and 24 inches. It is not necessary to have all these lengths of rules. It is better to select one or two which

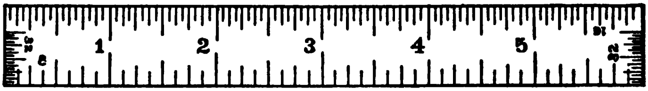


Fig. 1.—Rule.

will be most serviceable, such as 3″ and 12″, or 6″ and 12″, and add others when convenient. The steel rule can also be used for a straight edge to prove flat surfaces.

*Graduations.*—Rules are graduated on all four edges, one edge in eighths, another in sixteenths, another in thirty-seconds, and the last in sixty-fourths. In measuring a distance with a rule always use the graduations that are nearest to the fractional part of an inch desired. For instance, 2⅜″ is to be measured. Do not use the sixty-fourths graduations because the fine lines are confusing and hard to read; it is better to use the eighths for there will be less chance of error in the measurements and the dimensions will be read more easily.

Some rules have one edge graduated in twelfths and another in tenths; the tenths are graduated again in tenths, making hundreds. The twelfths are convenient for obtaining thirds and sixths of an inch, and the hundredths for fifths, tenths and twentieths of an inch.

The ends of some rules are graduated in thirty-seconds, which plan is convenient for small measurements in a narrow space.

*Scale.*—In shop parlance, a rule is sometimes called a *scale*—the term is so commonly used that it is considered correct,—although the definition of a rule is "an instrument by which short lengths are measured," and the definition of a scale is "an instrument graduated for the purpose of measuring extent or proportion," as a map drawn by a scale of ½" to 1 league or a plan where ½" equals 1 foot.

**Calipers.**—*Outside Calipers*—Outside calipers, Fig. 2, are a tool for measuring or gauging exter-

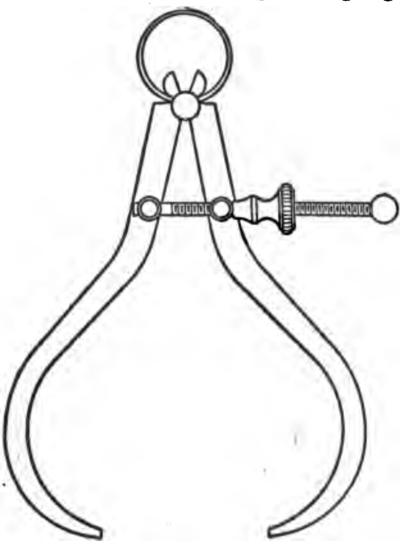


Fig. 2.—Outside Spring Calipers.

nal dimensions. They are made in two forms, spring calipers and firm joint. In the spring calipers for outside measurement (Fig. 2), the adjustment is made by means of the knurled nut. The spring tends to open the legs and the nut opens or closes and retains them in any position desired. In gauging a circular or cylindrical piece with spring calipers, care must be exercised in the handling, as it

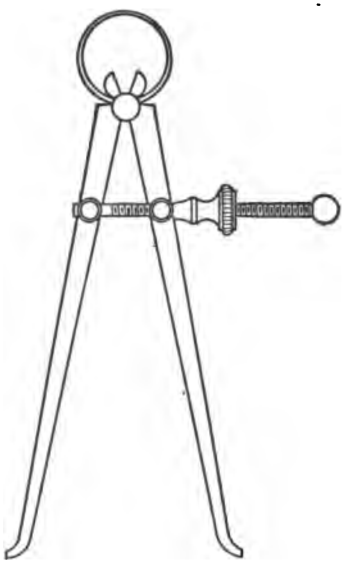


Fig. 3.—Inside Spring Calipers.

is easy to make the calipers slip over the work even if it is as much as 1/32″ large. The reason for this is that the calipers are made light and the legs will spring open with very little force and give an incorrect gauging or measurement.

*Proper Methods.*—When gauging a circular piece, a good way is to hold one foot of the calipers with a finger of the free hand and push the other foot over in a diametrical direction, at the same time vibrating the leg in a longitudinal direction. At the full diameter the caliper should not vibrate any but just slip over and touch the piece being tested very lightly. It

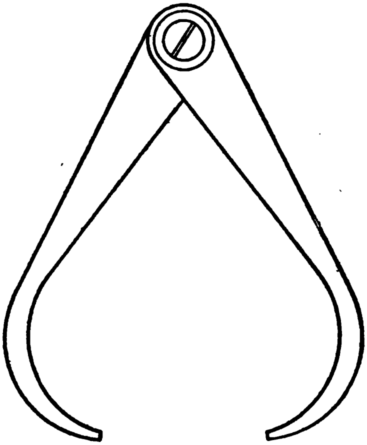


Fig. 4.—Firm Joint Calipers.

will take practice to get the proper feel and touch of calipers.

When setting the outside calipers to a dimension on the rule, the better way is to place one foot over on the end of the rule, the other foot lying on the graduated surface. Then by means of the adjusting nut, move the leg until the desired dimension is obtained. This is a more convenient way than by laying both feet on the graduated surface and trying to read the rule at two points at the same time. In the first method it is obvious that only one point or line will have to be observed or read and the calipers will be more easily adjusted.

*Inside Calipers.*—Inside calipers, Fig. 3, are an instrument for measuring or gauging internal dimen-

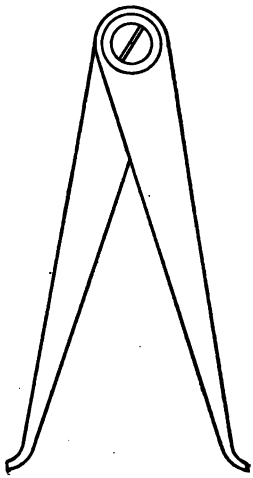


Fig. 5.—Firm Joint Calipers.

sions. They are also made in two forms, spring and firm joint. The same precaution must be taken as to spring, in fact more, for in gauging a hole, the spring must retain the legs in position, not the nut as in the case of the outside calipers. In transferring a dimension from the rule to the calipers, place one end of the rule against a flat surface and place one foot of the calipers against the same flat surface and on top of the graduated surface of the rule; lay the other foot on the rule and with the adjusting nut set the calipers to the desired dimension.

The firm joint calipers are shown in Figures 4 and 5. They are not provided with adjusting nuts. The

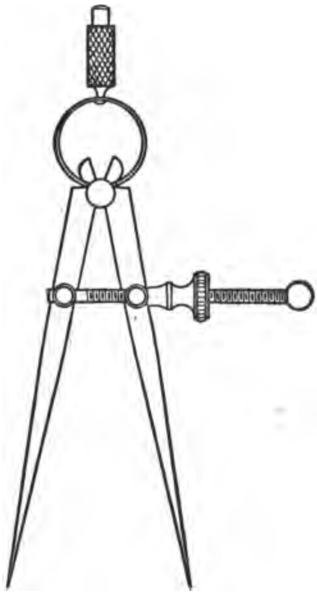


Fig. 6.—Dividers.

adjustment is made by striking the legs against something solid until the proper setting is obtained by successive trials on the rule. While these calipers are not easily adjusted, they are stiffer and are preferred by some to the spring joint calipers. In the larger sizes they are better on account of their stiffness.

**Dividers.**—Dividers are a tool for laying out work, such as circles, position points, centers, and for laying out one line parallel to another. The spring dividers are shown in Figure 6; Hermaphrodite, in Figure 7.

*Method of Use.*—In setting dividers to a dimension from a rule, place the rule flat on the bench or some

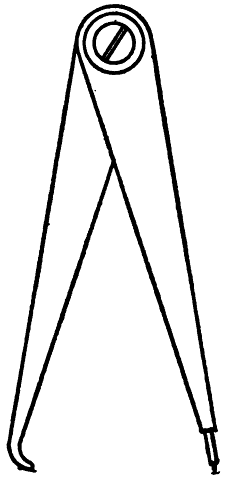


Fig. 7.—Hermaphrodite Calipers.

other convenient place. Then on a line which denotes one inch from the end of the rule, put one point of the dividers. With the adjusting nut open or close the legs until the other point falls in the desired measurement.

*Hermaphrodite Calipers.*—Hermaphrodite calipers, Figure 7, are a tool for laying out work such as finding the center of a cylinder, marking lines parallel with the edge of a square or rectangular piece, or locating a temporary center in a cylinder.

**Try square.**—The try square is a tool for testing

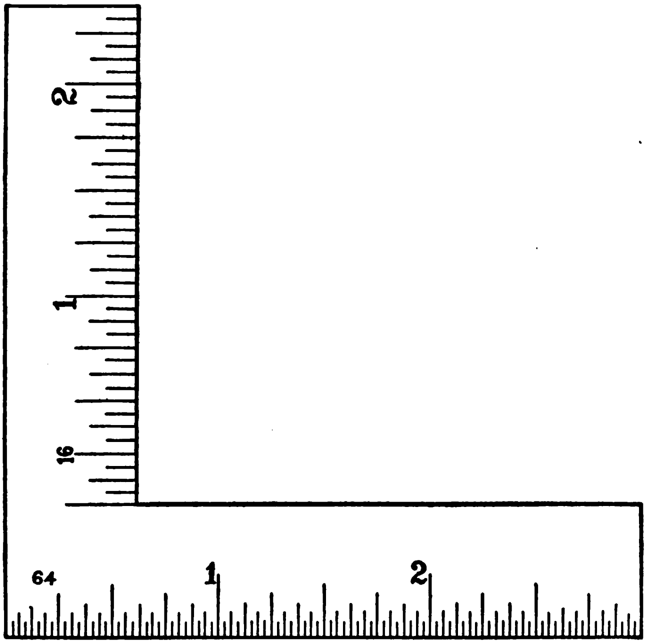



Fig. 8.—Thin Steel Square.

right angles. It is made in three forms: thin steel square without any beam, Figure 8; try square with beam, Figure 9; and combination square, Figure 10.

*Thin Steel Square.*—The thin steel square is for testing right angles in places where there is little room.

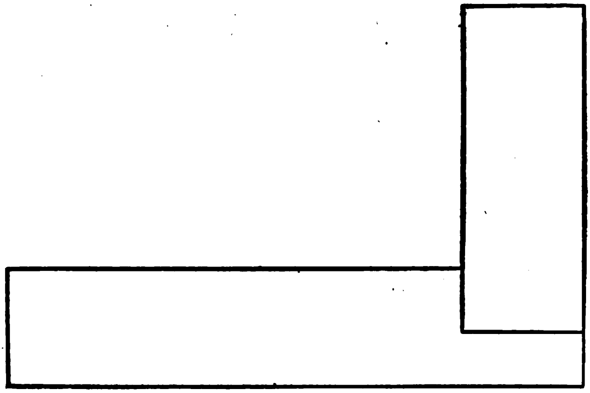


Fig. 9.—Beam Square.

It must be used with care because it does not have a beam to help hold it square. It is, therefore, easy to get a false test and the work may seem true when it is not.

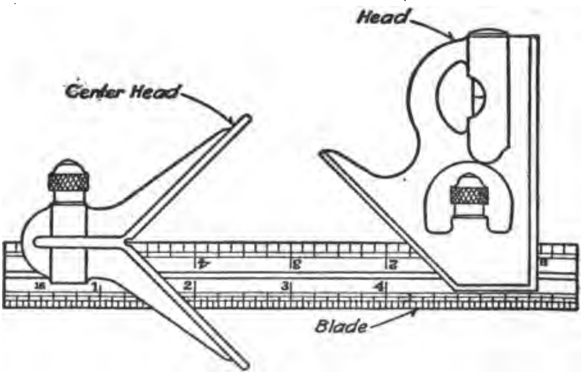



Fig. 10.—Combination Square.

*Beam Square.*—The beam square is used for general work. The beam aids the user in holding the square correctly and, if the square is true in all directions as it should be, the beam can be held in any position and

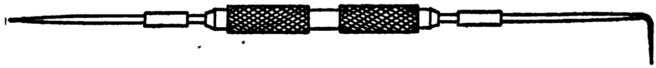


Fig. 11.—Scriber.

a true reading obtained. The beam is convenient for setting work true on the planer.

*Combination Square.*—The combination square is a handy tool. The blade can be made long or short to suit the work in hand. Also, 45° can be tested with the angular part of the head. The center head is con-

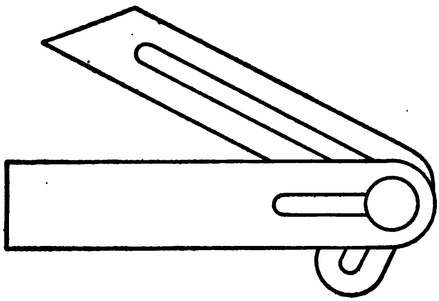


Fig. 12.—Bevel.

venient for finding the center of the end of a cylindrical piece of work and for testing 45° angles. The head is provided with a level and a scriber.

**Scriber.**—The scriber, Figure 11, is a tool for scratching lines on work when laying it out. The bent

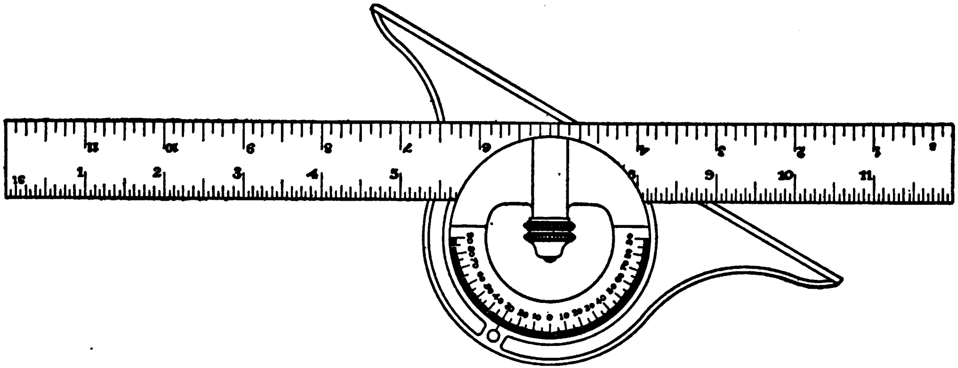


Fig. 13.—Bevel Protractor.

point is for getting into places inaccessible with the straight point.

**Bevel.**—The bevel, Figure 12, is a tool for testing angles. The bevel must be set with a gauge or to some

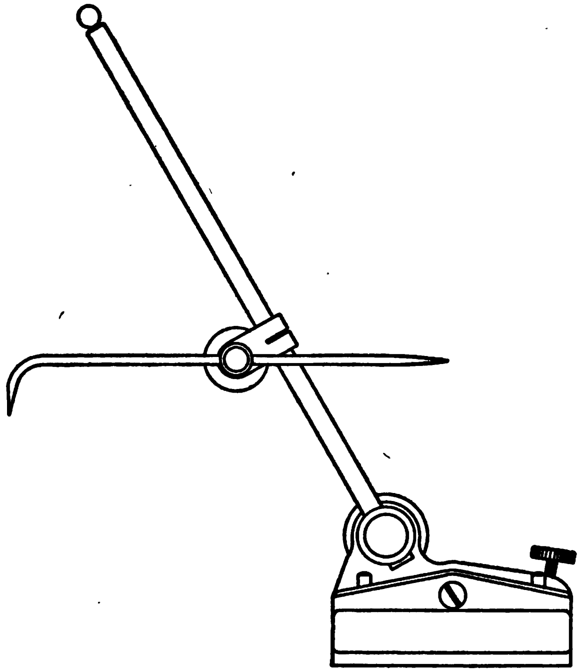


Fig. 14.—Surface Gauge.

piece of work where the angles are to be duplicated.

**Bevel Protractor.**—The bevel protractor, Figure 13, is a tool for laying out angles and for proving angles. The protractor differs from the bevel in that it is provided with a graduated circle and index point, sometimes with a vernier. This tool, therefore, contains within itself the means of setting it to any angle.

**Gauges.**—*Surface Gauge.*—The surface gauge, Figure 14, is a tool for setting work on the planer or shaper. It is also convenient for laying out work on

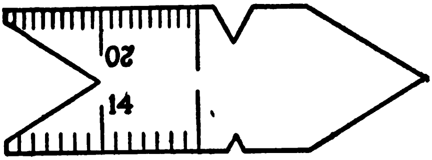



Fig. 15.—Center Gauge.

a surface table or plate. In using the surface gauge to set work on the planer, the base is placed on the platen of the planer, and with the hooked point different parts of the surface to be set are tested and adjusted to the proper position.

When the surface gauge is used on a laying-out table, the straight point is used as a scriber to locate or mark lines to work to.

*Center Gauge.*—The center gauge, Figure 15, is a tool used for testing lathe centers and for setting

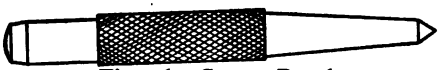


Fig. 16.—Center Punch.

threading tools on a lathe for inside and outside threading. All notches and the pointed end are 60° angles.

**Center Punch.**—The center punch, Figure 16, is a tool for making centers of circles and for marking lines that are likely to be effaced.

**Finer Tools.**—The tools described above are necessary for general work. A few of the finer tools are the micrometer caliper, vernier caliper, and vernier protractor.

**Micrometer Caliper.**—The micrometer caliper, Figure 17, is a tool for measuring very small dimensions ("micro" meaning small; "meter," measure). This tool is certainly the most useful invention ever devised for the machinist. Its simple, convenient, and rigid construction has never been excelled in any of the machinist's tools.

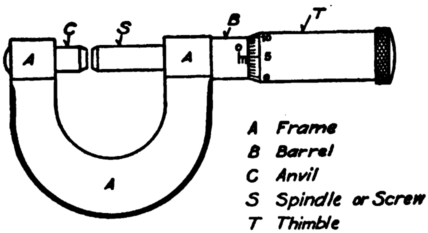



Fig. 17.—Micrometer Caliper.

*Names of Parts.*—The names of the different parts are given in Figure 17. The frame (A) and barrel are made in one piece, a drop forging. The anvil (C) is adjustable for wear. The screw and the thimble are made *one* after they are machined. The screw has forty threads to the inch. One inch on the barrel is divided into forty parts. Every fourth line is made long and marked 0, 1, 2, 3, 4, 5, etc., meaning 0, 1, 2, 3, 4, 5, etc., hundred-thousandths, also tenths of an inch. As the screw has forty threads per inch each revolution moves any part of the screw 1/40 of an inch. Therefore, if the beveled end of the thimble is on the first line or zero and its zero line is on the index line of the barrel, one revolution of the screw will represent 1/40 of an inch that the screw has moved; and, as the thimble is graduated into 25 parts on the beveled end, each part will represent a movement of 1/25 of 1/40 or 1/1000 of an inch.

*Decimal Equivalents.*—On the frame of some micrometers a table of decimal equivalents is stamped. If the frame is not so stamped, these equivalents can generally be found on charts which are sometimes hanging in shops. These charts are advertisements and can be obtained for the asking. If neither of these are at hand, one must use his own resources. It is easy to memorize a few decimal equivalents such as ½" = 500/1000, better expressed .500; ¼" = ½ of .500 or .250; ⅛" = .125; 1/16 = .0625; 1/32 = .0312; and 1/64 = .0156. Three thirty-seconds can easily be obtained by multiplying .0312 by three, or .0975.

*Reading Dimensions.*—In stating or reading dimensions, always read them in thousandths; for example, 17/64 = .275625. Read as a decimal in arithmetic; thus, "two hundred seventy-five thousand, six hundred twenty-five millionths" of an inch. Such a dimension will be comprehended by but few and will also seem an impossible and an impractical measurement, which it is, for no one can measure a millionth of an inch. Therefore, it is better to express this .275625 as .275 plus ⅝ of a thousandth or two hundred seventy-five and five-eighths thousandths which is as correct as millionths and more comprehensible. Always call a dimension so many thousandths, as ⅛ is .125; 3/16 is .187 and one-half thousandths; 7/32 is .218 and ¾ thousandths; and 17/64 is .275 and ⅝ thousandths.

Never use the cumbersome numbers of hundred thousandths or millionths. The fraction of a thousand will have to be estimated unless the micrometer is provided with a vernier reading to ten thousandths.

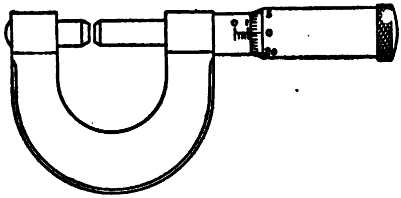


Fig. 18.—⅛″ Setting = .125.

*Examples.*—In Figure 18, the micrometer is set to read ⅛ of an inch or .125. The thimble has been unscrewed until its zero line is on the index line of the barrel at the fifth line from zero on the barrel. Now, if the line marked 1 on the barrel denotes

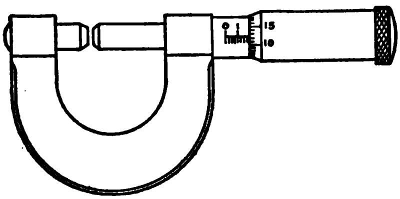


Fig. 19.—3/16″ Setting = .1875.

100/1000 and every line or space equals 25/1000, the screw has been opened 100/1000 plus 25/1000 or 125/1000 = ⅛ inch. In Figure 19 the setting is for 3/16″ which is .1875 or 187½/1000. The thimble has been opened to the seventh line from zero on the barrel which equals 175/1000 and it has then been opened 12½ thousandths more, or 2½ from 10 on the thimble, making the reading 187½ thousandths or 3/16 inch. With practice, one will become proficient in reading or in setting the micrometer.

*Proper Use.*—The proper way to use a micrometer: Never take hold of the thimble with one hand and whirl the frame around to open or close the screw, it is not good for the instrument. Always hold the frame in the left hand and with the first finger and thumb of the right hand open or close the screw.

In gauging a piece with a micrometer, open it a little wider than the piece to be measured, slip the anvil and point of the screw over the piece, close the screw until it touches the work, and then take the reading. Never try to gauge a circular piece in the lathe while the piece is revolving. The micrometer might catch and be ruined or at least injured.

**Vernier Caliper.**—The vernier caliper, Figure 20, is a tool for measuring inches and thousandths of an inch. It consists of a beam with a series of graduations divided on its face. The divisions are inches (the tool being capable of measuring 6″ in extent), the inches are divided into tenths, and the tenths are divided into four parts equaling fortieths of an inch or 25/1000. The end of the beam has a piece called a jaw. On the beam is another sliding jaw which carries a vernier. The sliding jaw and vernier are adjusted by means of the screw and nut. The screw is fastened to the sliding jaw and passes through the slow-motion clamp which holds the adjusting nut. To set the caliper, move both the sliding jaw and the slow-

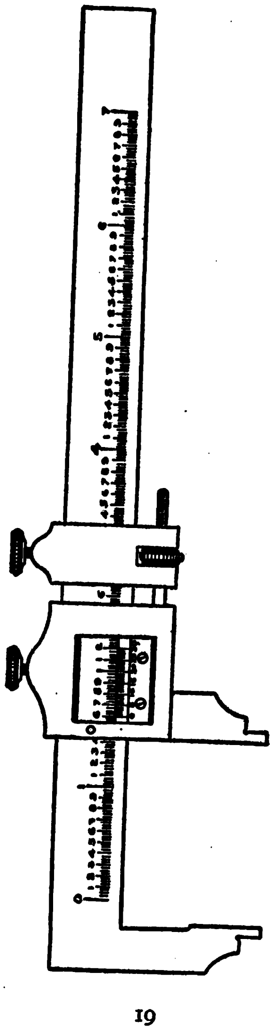


Fig. 20.—Vernier Caliper.

motion clamp to approximately the proper position, clamp the slow-motion clamp by means of its clamp screw, and with the adjusting nut make the final adjustment, and then clamp the sliding jaw.

*Divisions.*—The vernier is as long as 24 divisions on the beam, but it is divided into 25 parts; therefore, each division on the vernier is 1/1000 of an inch shorter than a division on the beam, or 1/25 of 1/40 = 1/1000 of an inch. If the zero on the vernier is placed upon a line on the beam, the first line from zero on the vernier will be just 1/1000 of an inch from the next line on the beam. So, if the vernier is moved until its first line from zero coincides with the first line from the starting point on the beam, the vernier and jaw will have been moved 1/1000 of an inch; and so on until 25/1000 has been moved by vernier and jaw. The process can be repeated because zero on vernier will now be on the next line from the starting point on the beam.

*Use.*—The vernier caliper is convenient because a large range in inches can be measured with it, but in testing different diameters of a shaft it is useless as the jaws are short and will not reach to the center of the shaft. Only the end of a large piece of round material can be measured.

**Vernier Protractor.**—The vernier protractor, Figure 21, is a tool for testing or measuring angles: It is provided with a graduated circle and vernier. Some have a vernier reading to 5 minutes or 1/12 of a degree; the finer read to 1 minute or 1/60 of a degree.

The difference between the protractor and the vernier protractor is that the latter reads to a finer degree of accuracy than does the former.

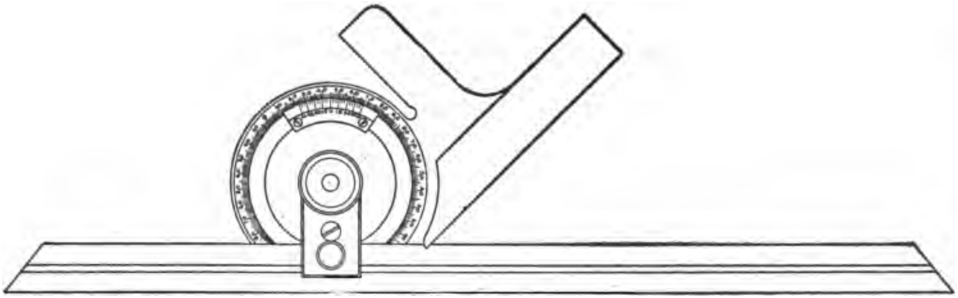


Fig. 21.—Vernier Protractor.

## GENERAL TOOLS

There are a number of tools which are almost indispensable in a machine shop. The most important of these are shown in Plates 1 and 2.

**Plate 1.**—The monkey wrench, No. 1, is a very handy tool for all wrench work, as it is adjustable. When using it, the pressure should always be applied in the direction of the arrow as shown. If applied in the opposite direction, there is a liability of straining the wrench.

The Stillson pipe wrench, No. 2, is designed for screwing pieces of pipe together. This wrench can be used for inserting studs in a tapped hole.

No. 3 is a wrench for turning a tap when tapping a hole. It is usually made adjustable for different sizes of taps.

No. 4 is a single-end Hex wrench. This is sometimes made double, the other end being for another size Hex.

No. 5 is a 15° angle wrench. This is also made double. The opening in the end of the wrench is at an angle of 15° with the handle. This permits the turning of a Hex nut completely around where the swing of the handle is limited to 30°.

No. 6 is a 22½° angle wrench. This is capable of turning a square nut completely around where the swing of the handle is limited to 45°.

No. 7 is a wrench for round nuts which have holes in their faces to receive the two wrench pins and is called a pin face spanner.

No. 8 is a hook spanner. This is milled with a hook

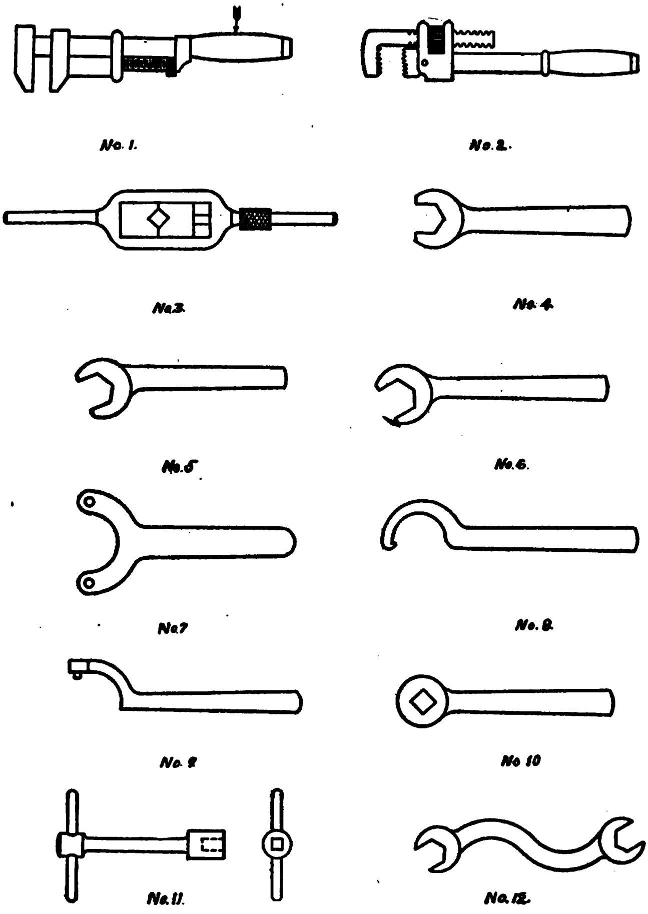



Plate I.—Wrenches.

at the end to fit notches which are milled in the circumference of round nuts.

No. 9.—Nuts which have holes drilled in their periphery can be rotated with the pin spanner.

No. 10 is a box wrench convenient for places where it is desirable to leave the wrench on the nut or screw. It is also stronger then the open-end wrench.

No. 11 is a socket wrench which is used in places, where the nut is below the surface and where it is impossible to use any other wrench.

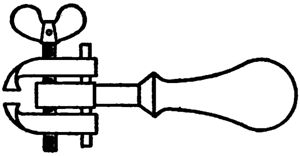
No. 12. The S-wrench is so called because it somewhat resembles the letter S. This wrench is for general utility.

**Plate 2.**—No. 1 is a hand vise for holding small pieces of work when filing. The work can easily be turned to get at different sides.

No. 2 is a hack saw. This tool is well adapted for sawing off pieces of metal which can be held in the vise or for sawing off the ends of bolts which are longer than necessary. When sawing with the hack saw, the strokes should not exceed 60 per minute and the pressure should not be excessive as it tends to break the teeth.

No. 3 is a ratchet drill. This is a tool for turning a drill or tap. A pawl on the handle engages the teeth of a ratchet wheel on the barrel. The handle is given part of a revolution and the pawl engages one or more teeth each time the handle is swung. By giving the handle several swings the drill or tap is turned completely around.

No. 4, "C" clamp, is a clamp shaped like the letter C and is used for holding work in various ways. Some-



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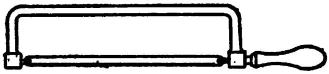

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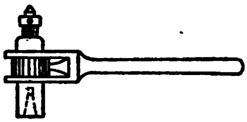

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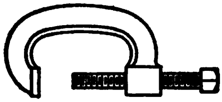

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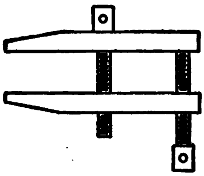

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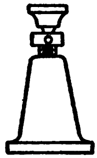
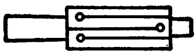


No. 6

No. 7.



No. 8

Plate II.—Tools.

times it is made of cast iron but more often it is drop-forged.

No. 5 is a machinist's clamp for holding jigs or templates on work or for holding two pieces of work together which are to be drilled, filed, or machined.

No. 6 is a planer jack. This is a small screw jack for leveling and holding work on the planer bed. It makes a very good adjustable packing block.

No. 7 is a mandrel or arbor. This is for holding work which has been bored and is to be turned or otherwise worked on. It is made of high carbon steel, tempered and ground true with a slight taper of about ½/1000 of an inch in each inch of its length.

No. 8 is an expansion mandrel. This form can be varied in diameter from its nominal size to about ⅛ of an inch larger.

## Fastening Devices

**Plates 3 and 4.**—In Plates 3 and 4 are shown a number of fastening devices such as cap screws, machine screws, set screws, and bolts.

*Cap Screws.*—Cap screws are machined straight from point to head. The heads are finished. Up to four inches long they are usually threaded for three-fourths of their length; when longer, for about one-half their length. The length is measured from what is called "under the head," except in the case of countersunk head screws which are measured over all. Cap screw sizes vary by sixteenths and eighths of an inch and are made in sizes from ¼ inch to 1¼ inch in diameter.

*Machine Screws.*—Machine screws are similar to cap screws but are made to the machine screw gauge

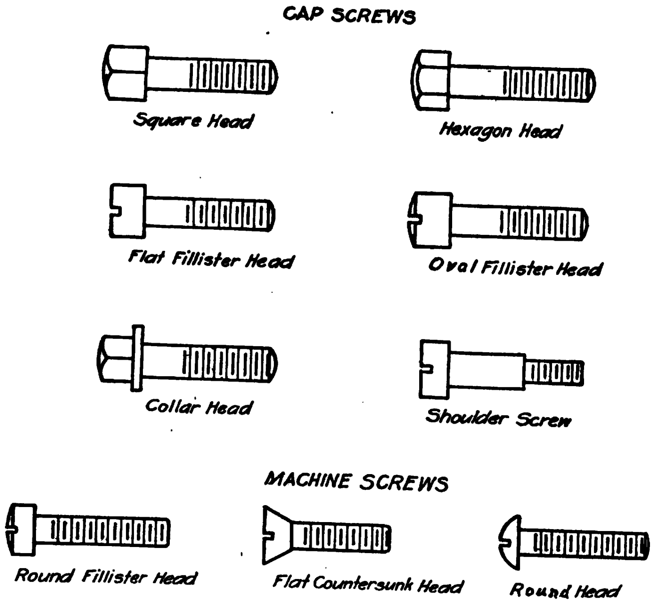



Plate III.—Cap Screws and Machine Screws.

sizes. They are also made in smaller sizes than cap screws and run below ¼ inch in diameter. The threads also have a different standard from that of cap screws. The size of the screw and the thread is generally expressed thus: 10-30, meaning that the body is No. 10 and the screw has 30 threads to the inch.

*Set Screws.*—Set screws are for securing pulleys to shafting or anything that is to remain in one certain position at all times. They are threaded the full length of the body and may or may not be necked; that is, the body is reduced at the head to the root diameter of the thread. The head has generally the same diameter across the flats as has the body of the screws. Set screws are usually case-hardened.

Some set screws have no head and are called headless; the thread runs the whole length and a screw driver slot is made in one end for inserting it into the tapped hole.

Set screws have the several different kinds of points as shown in Plate 4.

*Bolts.*—On Plate 4 are shown also a few of the different kinds of bolts. The through bolt is used for clamping two pieces of material together; the eye bolt, for holding the end of a spring, or it can be placed on a piece of machinery for the purpose of lifting it by a crane or hoist. Sometimes the eye bolt is used without a nut and is screwed into the piece, as in the case of a dynamo or of the caps of a heavy pillow block.

The U and V bolts are for clamping round things to a flat surface and for holding up pipe lines to the ceiling or beams.

The boiler patch bolt is used for fastening patches

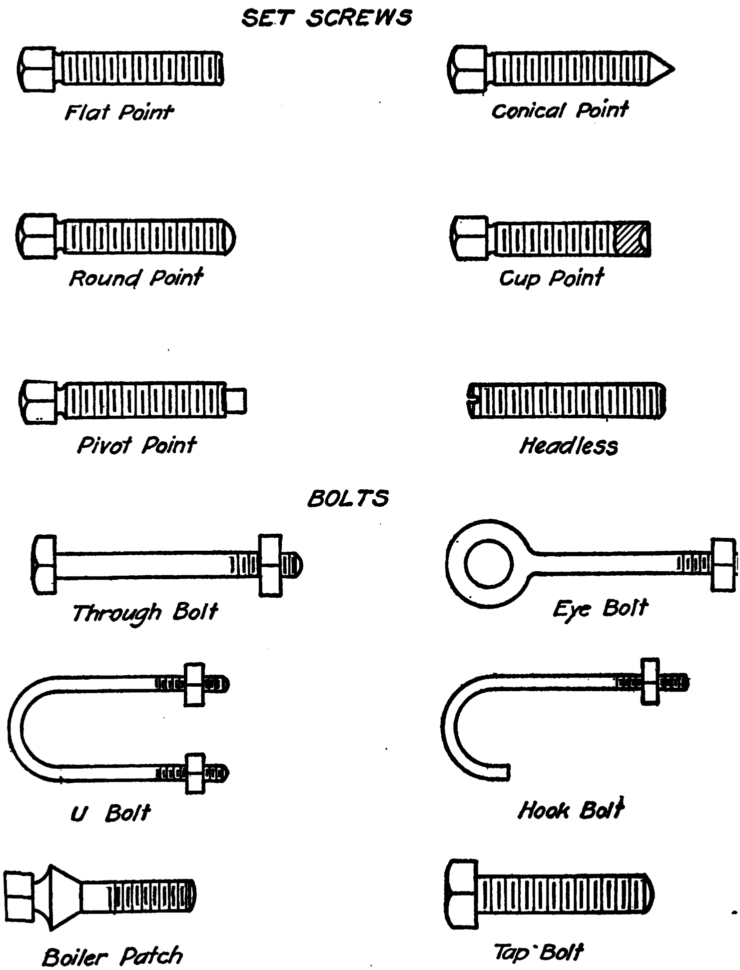



Plate IV.—Set Screws and Bolts.

on boilers. The square head is either twisted or broken off after the bolt is screwed into place.

Tap bolts are generally threaded the full length of the body. Only the point and the underside of the head are finished. The die is run over the rough bolt without its being machined. These bolts are made with square and hexagonal heads and are used as a rule for a rough class of work.

## QUESTIONS ON CHAPTER I

1. To what other use than measuring short lengths can a steel rule be applied?
2. For what purpose are the graduations on the end of a steel rule?
3. What is the difference between a rule and a scale?
4. Name two forms of inside and outside calipers.
5. What precaution must be taken in gauging a circular piece of work with the outside calipers?
6. Describe the method of using outside calipers in gauging a circular piece of work.
7. Explain the method of transferring a dimension from the rule to calipers for both inside and outside calipers.
8. How are spring joint calipers and firm joint calipers adjusted?
9. State how to transfer a dimension from a rule to the dividers.
10. State the difference between dividers and Hermaphrodite calipers.
11. Give some of the uses for Hermaphrodite calipers.
12. Name three different kinds of squares.
13. For what purpose is the beam on the square?
14. What special conveniences does the combination square possess?

15. What is a scriber?
16. What is the difference between a bevel and a bevel protractor?
17. On what machines is a surface gauge used?
18. What is a center gauge?
19. How many threads to the inch has a micrometer screw?
20. What is the reading of a micrometer when the third division, plus, on the thimble is on the index line of the barrel and the thimble edge is between the line marked 4 and the seventeenth line from zero on the barrel?
21. Explain the proper way to gauge a piece with the micrometer.
22. Can the vernier caliper be used to test the parallelism of a large shaft?
23. What is the difference between a protractor and a vernier protractor?

## CHAPTER II

### CHIPPING, FILING, AND SCRAPING

**Chipping.**—Chipping is removing metal by means of a hammer and a chisel.

*Hammers.*—A machinist's hammer is generally a ball peen, sometimes a straight or cross peen. A good

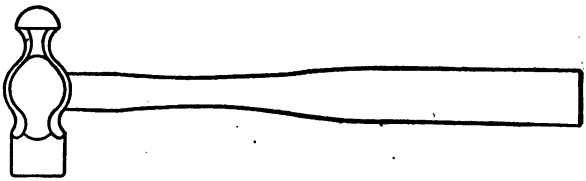


Fig. 22.—Ball Peen Hammer.

weight for a machinist's hammer is from a pound to a pound and one-half.

Figure 22 shows a ball peen hammer. Figures 23 and 24 show a straight and a cross peen.

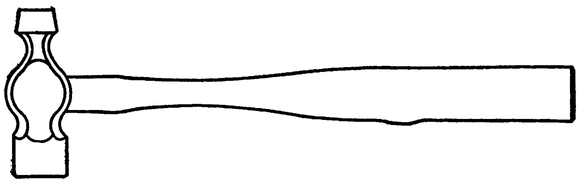


Fig. 23.—Straight Peen Hammer.

*Hammer Handle.*—The handle should be made of hickory. The axis of the hammer head and the handle should not be exactly at a right angle, but at a little less. The handle should hang down so that when swinging, the face of the hammer will strike the chisel squarely. The arm in swinging the hammer naturally

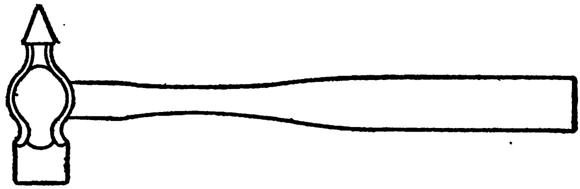


Fig. 24.—Cross Peen Hammer.

describes an arc and if the handle is at a little angle with the head it will strike the chisel square. This must not be carried too far, for when a flat blow is to be struck on a plate or flat surface, the knuckles of the hand will hit the plate, and to avoid this one would have to keep the hand up and in so doing make the edge of the hammer strike and not the whole face. The handle should be thin near the hammer head to give it spring. If made this way, it is not so hard on the wrist of the operator when chipping.

**Chisels.**—The names of the chipping chisels are:

Flat chisel
Side chisel
Cape chisel
Diamond point
Gouge
Bent gouge

These chisels are made of octagonal high carbon steel, the points are forged to shape and tempered. The final shape of the point is made with the emery wheel or grindstone.

*Use of Emery Wheel.*—The emery wheel or grindstone in a shop is only true and straight for a short time after it is trued up. If the chisel is held on the stone with its face parallel to the axis of the stone, a proper cutting edge will be produced only while the

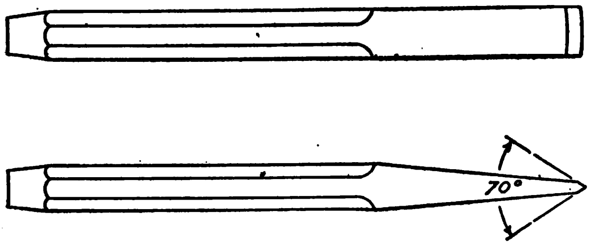



Fig. 25.—Flat Chisel.

stone is true and straight. As this condition exists only for a short time, it is better to hold the chisel at an angle of about 45° to the axis of the stone and to move it in an arc over the surface of the stone. In this way the whole surface of the chisel passes the high point of the stone, thereby grinding nearly a straight line on the face of the chisel.

*Flat Chisel.*—The flat chisel, Figure 25, is for chipping a flat surface. It should be ground to an angle of about 70° for cast iron, and for steel or brass to an angle of about 60°. For softer metals such as lead or babbitt metal, the angle can be less than 60°.

The facets should be a little convex, but never concave. In Figure 25 the facet is shown too convex. This convexity is for a two-fold purpose: First, to keep the corners from digging in as it is hard to hold

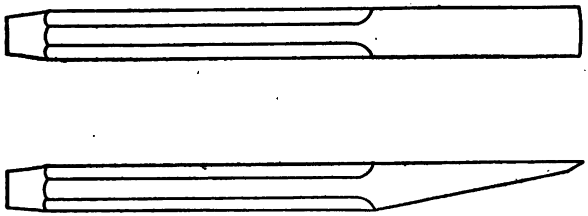


Fig. 26.—Side Chisel.

the chisel perfectly straight; second, to give a wedge action to the chisel when entering the metal.

*Side Chisel.*—Side chisel, Figure 26, is a chisel for chipping mortises, or narrow places, where there is not room for the flat chisel to work in; also, for chip-

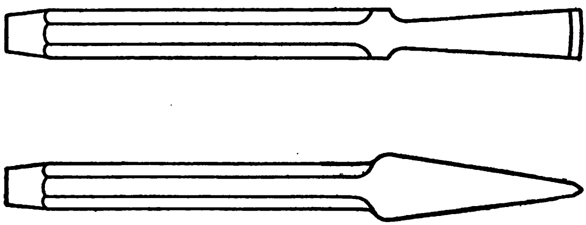


Fig. 27.—Cape Chisel.

ping out the corners of the bottom of a square hole. One side of this chisel is forged nearly parallel to the axis of the chisel, the other side at an angle to the axis. The point is beveled on the angular side.

The angle or bevel is about 35° or one-half of the flat chisel angle.

*Cape Chisel.*—Cape chisel, Figure 27, is a chisel for chipping key ways or grooves. It is ground like the

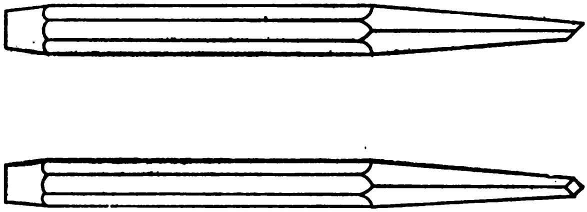


Fig. 28.—Diamond Point Chisel.

flat chisel for general work, but for cutting keyways in long hubs it is ground like the side chisel. The cape chisel is also good for grooving a large flat surface where considerable metal is to be removed. Cutting grooves across the surface leaves a space a little nar-

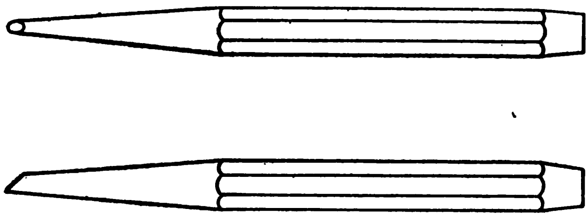


Fig. 29.—Gouge.

rower than the flat chisel, which space can then be removed with the flat chisel more rapidly and better.

*Diamond Point Chisel.*—Diamond point chisel, Figure 28, is a chisel for chipping square corners. This chisel is also convenient for cutting a hole in a plate of steel. By cutting a groove with the diamond point, following the shape to be cut out, the piece can be easily removed with the hammer. The edges of the hole made in this way will be beveled, but can be chipped square after the piece is removed.

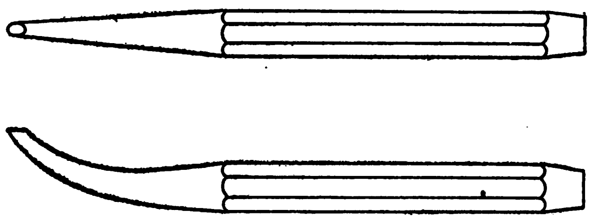


Fig. 30.—Bent Gouge.

*Gouges.*—Gouges, Figures 29 and 30, are chisels for cutting oil grooves in bearings and for chipping irregular surfaces, or surfaces which are not flat. The bent gouge in figure 30 is convenient for cutting oil grooves in small bearings, the bend making it possible to get around in bearings of small diameter.

**Vises.**—When chipping or filing small pieces of work, a vise is used to hold the piece. Large pieces which are heavy will hold themselves by their own weight.

There are three general kinds of vises; namely, the stationary bottom or base, the swivel bottom or base, the swivel base and swivel jaw. The first is a plain vise for general work. In the second the base of the vise swivels, which is useful when it is desirable to place the vise in different positions for convenient working. In the third, both the base and back jaw of the vise swivels. This vise has the additional convenience of its being adapted for holding tapered pieces such as taper keys, etc.

A vise is always fastened to the front of the bench. An ideal height for the top of the jaws of a vise is to the operator's elbow which, of course, varies with different heights of men from about 40 to 44 inches; an average of 42 inches will, therefore, do for general purposes. The reason that the elbow height is desirable is this: in filing, the operator has a free and natural motion with his arms.

**Filing.**—Filing is removing metal by means of a file. The distinguishing features of files are:

1. Their length which is always measured exclusive of their tang;
2. Their kind or name which has reference to the shape, such as flat, half-round, and round;
3. Their cut which has reference to the character and to the relative degrees of coarseness of the teeth.

*Tang.*—The *tang* of a file is the part of the file prepared for the handle and is never included in the length. In general, the length of files bears no fixed proportion to either their width or thickness, even though they be of the same kind.

*Kind.*—By ***kind*** is meant the different shapes of files which are distinguished by certain technical names as flat, half-round, etc. The kinds are divided from the form of their cross sections into three geometrical classes; namely, quadrangular sections, circular sections, and triangular sections. Odd and irregular forms such as knife, cabinet, crossing, etc., are collected under miscellaneous sections.

*Cuts.*—The *cuts* of files are single cut, double cut, and rasp cut; and with reference to the coarseness of the teeth of these cuts, there are the rough, coarse, second cut, smooth, and dead smooth.

Figures 31, 32, and 33, show single cut, double cut, and rasp cut files.

Fig. 31.—Single Cut File.

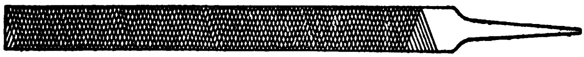


Fig. 32.—Double Cut File.

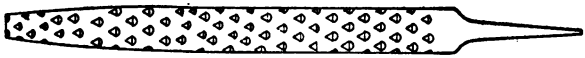


Fig. 33.—Rasp Cut File.

**File Terms.**—The following terms are used in reference to files: Back—a term used to describe the convex side of half-rounds, cabinets, pitsaws, and other files of similar cross-sectional shape; Bellied—a term used to describe a file having a fullness in the center; Blunt—a term applied in describing files which preserve their shape throughout from point to tang; Safe-edge means that a file has one or more of its edges or sides smooth or uncut, that it may be applied to the work without injury to that part which does not need to be filed.

**An Exercise in Chipping and Filing.**—The rectangular piece shown in Figure 34 is to be chipped and filed to the dimensions given. All surfaces are to be straight, parallel, and square with each other. One-sixteenth of an inch has been left for surfacing.

*Chipping.*—First, grip the piece in the vise jaws at E and F. With the steel rule test the surface A for straightness. If it is fairly flat or straight, then with

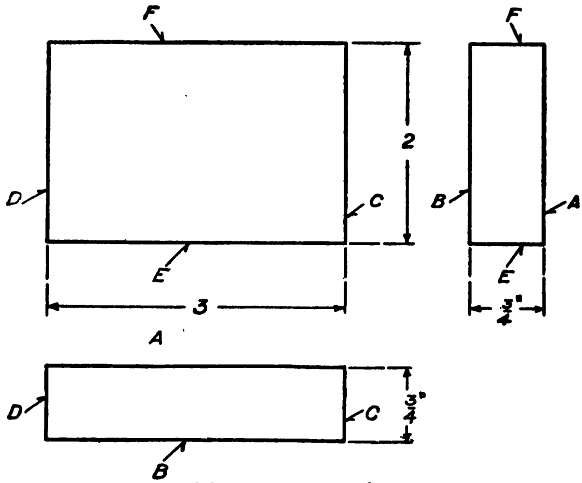



Fig. 34.—Example.

the flat chisel chip this surface all over, taking the same amount off at all points. The cut should be about 3/64 of an inch deep, thus leaving 1/64 for filing. The large surface A or B should be worked first, because it will give a better surface from which to test the others. After surface A has been chipped flat, reverse the piece in the vise and chip surface B parallel to A. To test the parallelism, use the outside caliper, trying it on all four corners. When testing for parallelism make sure there has been enough left for filing. About 1/64 of an inch will be enough if the chipping has been well done; if the surface is rough, better leave a little more so as to be sure that the file will remove all chisel marks. Next, grip the piece in the vise at A and B, using copper jaws in the vise to avoid marring the surfaces already chipped. Chip E straight and *square* with A. Also chip F straight and square with A and *parallel* with E, leaving enough for filing as in the case of A and B. Now chip C and D, making the same tests as for E and F, with the additional test of C and D square with either E or F.

*Chipping Methods.*—When chipping these surfaces, chip from the outside of the piece towards the center; and when at the center, better reverse the piece in the vise and chip again to the center. If the chipping is carried to the opposite side, there is danger of breaking the corners off and of spoiling the square edges which are required by the drawing. If the edges were to be beveled, the bevel would probably cover up the defect; but one can never tell just how much will break off and it is better to be on the safe side and not to run any such risk.

When chipping always grasp the chisel near the head, not near the point. If grasped near the point, a small motion of the hand will give a larger motion to the head of the chisel, thereby increasing the chances of the hammer missing the chisel and hitting the hand. Again, if grasped near the head, the operator has a less obstructed view of the work. The hammer handle should be grasped well out, near the end opposite the head of the hammer, and a free, easy swing should be given to the hammer.

When chipping, the operator should watch the point or cutting part of the chisel, not the head. The beginner generally wants to watch the head. He thinks that by so doing, he is less liable to miss the chisel and hit his hand, but with practice he soon learns to cease looking at the head of the chisel and to watch the point, which is the correct way.

*Filing.*—After the piece has been chipped all over, proceed to file it in the same order as the chipping was done, A and B first, etc.

Use a coarse file ten or twelve inches long. Before using the file, see that it is properly put in the handle. The tang should be forced well up to the shoulder. A good way to avoid splitting the handle is to take an old file of about the same dimension or size of tang, to heat the tang and drive it in to nearly the proper depth, and then to insert the file to be used until the shoulder is well up to the ferrule. See that the handle is straight with the file. Never use a file without a handle.

*Filing Methods.*—By sighting along the file, note which side is convex or bellied and use this side for rough filing. This convexity is for a twofold purpose. First, when applying pressure on the file, this action tends to bend it. If the file were straight, this bending or springing would naturally cause the file to operate on the edges of the work and make it convex or high in the center. It is surprising how easily a file is sprung or bent when pressure is applied. Secondly, if the file is convex (only a small portion of the teeth catch the work at one time and the file gets what is called a "bite." In using the file, the handle should be grasped in such a manner that its end will fit into the fleshy part of the palm below the joint of the little finger with the thumb lying along the top of the handle in the direction of its length, the end of the finger pointing upwards or nearly in the direction of the operator's face. Grasp the point of the file by the thumb and first two fingers. This method is good for light strokes. For heavy strokes it is better to grasp the point of the file on top with the fleshy part of the hand near the wrist and with the fingers grasp the under side of the file. For beginners it is better to follow these directions rather than to grasp the file at random. (It is true that good filing is done by experts who do not follow any set rules, but grasp the file in their own way and get good results.)

The natural movement of the hands and arms in filing is to carry the file in circular lines, the joints of the arms being the center of motion; this movement given to a convex file would apparently give a concavity to the work, but the real tendency is the reverse, owing to the work acting as a fulcrum over which the file moves with more or less of a rocking motion giving an actual convexity to the surface.

**Filing Aim.**—In filing, the aim should be to cause the file to depart only so much from a true straight line as will be necessary to *feel* that each part of its stroke is brought into exact contact with the desired portion of the work; the mind must be concentrated upon just where the file is cutting. The difficulties to be overcome in making a true flat surface with a file require much practice on the part of the operator. In filing the first surface in Figure 34, a steel rule is sufficient for testing its flatness. When it is true to the steel rule or straight edge it should then be tested on a surface plate to see that there is no "wind" in the surface. By "wind" is meant that two diagonal corners are higher than the other two. This test is made by laying the piece on a surface plate and with the fingers pressing on diagonal corners to see if there is any rocking motion. If there is no rock in these first two, then try the other two corners; and, if there is no rock in these, the piece is flat or at least the four corners are in the same plane. When one true surface is obtained, the others can be made true

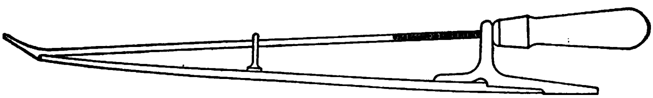


Fig. 35.—Surface File Holder.

with it by testing them with the calipers and square, the calipers for testing parallelism and the square for right angles, of course using the straight edge all the time. After the piece has been rough filed, true and to size, it is comparatively easy to finish all surfaces with a finer file; and then with emery cloth, should a polished surface be desired.

**Surface File Holder.**—Figure 35 shows a surface file holder. With a holder like this, any flat file can be used to file a surface larger than itself. The handle at the end of the rod is provided with a nut. By tightening this nut, the file is made convex on the cutting side. The handle is above the file, thus permitting the hand to clear the work when the file passes over the surface.

**Draw-filing.**—Files are sometimes used by grasping at each end and moving them sideways across the work. This operation is known as draw-filing and is usually done in laying the strokes of turned work lengthwise instead of circular, as left from the lathe finish; as well as when giving a final fit to a shaft that is to receive a coupling. Draw-filing is only done where no considerable amount of material is to be removed or where a smooth finish is desired. Properly done work may be finished somewhat finer and the scratches more closely congregated as the teeth of the file produce a shearing or shaving cut.

**Scraping.**—To obtain a more perfect surface, scraping must be resorted to. Figure 36 shows one style of scraper, the double-ended type. This is made

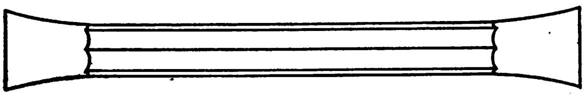


Fig. 36.—Scraper.

from one-half inch octagonal steel. Both ends are flattened and hardened as much as possible. The cutting edges should be ground straight in both directions. Another style of scraper can be made from an old half-round file. All the teeth are ground off and the edges made sharp. This style is good for scraping round bearings, such as journals for rotating shafts.

One naturally thinks that a piece of work comes perfect from the machine, but such is not the case, especially work done on the planer or the shaper. The clamping of a piece to the machine tends to distort it and no matter how carefully it is clamped it will be somewhat affected. To correct this defect, hand filing and scraping must be applied locally. Round journals which are turned between the centers of the lathe are the most nearly perfect pieces of work as there is no clamping in this operation, but even these are not perfect owing to the irregular condition of the piece in the rough. The tool to a certain extent follows this irregularity.

**Surface Plate.**—For small flat surfaces a surface plate is used to test their accuracy. The piece is filed as flat as possible and then rubbed on the surface plate, or the surface plate is rubbed on the piece, whichever is more convenient. To show where the piece bears on the test plate, a thin coat of red lead is applied all over the test plate before it is rubbed on the surface to be tested. Small bearing spots will be observed. These spots which are high must be scraped down until the test plate makes marks all over the piece which is being tested. Care must be exercised in applying the red lead to the test plate. If the film of red lead is heavy in some places and light in others, the test will not be true and if in the next trial the heavy spots are in another place it will seem as if the piece is becoming worse instead of better. The conclusion the beginner generally forms is that, "The longer I work on this, the worse it gets," and this is true; but it is because the tests have carelessly been performed. An excellent way to spread the red lead on a test plate is first to apply a small quantity of the marking substance and with the fingers distribute it all over the plate. It will not be even with this operation, but can be made so by using the fleshy part of the hand between the lower joint of the little finger and the wrist, holding the hand with the thumb pointing up, and by moving it from right to left over the test plate. The marking material will then be quite evenly spread over the surface.

**Scraping Methods.**—When using the scraper, hold it at an angle of about 45° or at the angle it takes hold the best. If the scraper is held at too low an angle, it tends to slip over the surface and to have its edge burnished. It does not cut well when the edge is burnished. Be careful to scrape only the high points, never scrape where there is no deposit of the

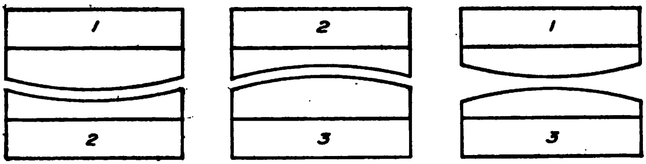



Fig. 37.—Master Plates.

marking material. A good way to tell when progress is being made is to note the surface *grow*, that is, if the spots are becoming longer or growing. Large bearings and other than flat surfaces are scraped by using the two pieces which work together as gauges.

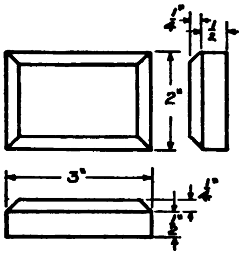
**Master Plate.**—How to make a master plate: Take three plates all of the same size and mark them 1, 2, and 3, as shown in Figure 37. Surface these three plates as flat as possible. Fit No. 1 and No. 2 together; then fit No. 3 to No. 2, not operating any on No. 2. Now test No. 1 and No. 3; the error observed between these two plates will be twice the error of No. 1. In Figure 37, for the sake of illustration, No. 1 and No. 2 are shown with considerable error, No. 1 being convex and No. 2 concave. Now if No. 3 is made to fit No. 2 (not working on No. 2) and then No. 1 and No. 3 are tried together, it is evident that the error shown is just twice the error in No. 1. It is now known that No. 1 is convex; therefore, a correction is made on No. 1 for this error and No. 2 is worked again to No. 1; and again No. 3 is worked to No. 2, and a test is made with No. 1 and No. 3. When there is no error between No. 1 and No. 3, all three plates are perfect and any one will do for a master plate. It is obvious that to make any one of these correct, it is necessary to make the three plates as described.

## QUESTIONS ON CHAPTER II

1. Define the term chipping.
2. Give the names of three different kinds of machinist's hammers.
3. About what weight should a machinist's hammer be?
4. What is the objection to too great an angle in the handle of a machinist's hammer?
5. For what purpose is the handle made thin?
6. Give the names of six kinds of chisels.
7. Of what kind of steel are chisels made?
8. Explain the proper way to hold a chisel on the grinding wheel when grinding it.
9. How should a chisel be ground?
10. What kind of chisel should be used in chipping a mortise?
11. What is a cape chisel used for?
12. What kind of chisel should be used for chipping the corners of square holes?
13. What is the name of the chisel for cutting oil grooves in small bearings?

14. What is a vise?
15. In what way do vises differ?
16. What is the ideal height of a vise?
17. Give the definition of a file.
18. What are the distinguishing features of files?
19. What part of a file is not included in stating the length?
20. Name the different cuts of files.
21. Give some of the terms used in reference to files.
22. Explain the method of holding a file.
23. Why are copper jaws sometimes used when gripping a piece in the vise?
24. How is the breaking of corners avoided when chipping?
25. Where should the chisel be grasped when chipping?
26. Should the head or the point of the chisel be watched when chipping?
27. What is the first thing to be observed when using a file?
28. What is meant by the term "Bellied"?
29. Describe how the right and left hands should grasp the file.
30. What is the test for "wind" in a flat piece?
31. Describe a special surface file holder.
32. What is draw-filing?
33. When is it proper to draw-file?
34. When is it necessary to scrape a surface?
35. How should the edge of a scraper be ground?
36. Describe the method of making a master plate.

## EXERCISES FOR PRACTICE



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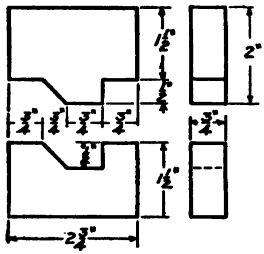

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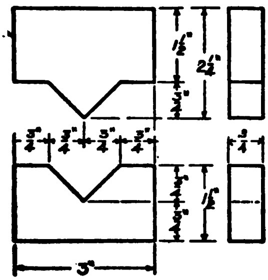

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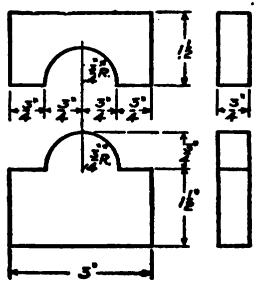

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# CHAPTER III

## DRILLS AND DRILLING MACHINES

**Drills.**—A drill is a tool for making holes in metal. There are a few kinds of drills, but the twist drill is the most universally used. It is made and kept in stock in all sizes from .0135 inch to 2 inches in diameter. From No. 80 which is .0135 inch in diameter to No. 1 which is .2280 inch in diameter, the sizes increase by only a few thousandths of an inch. From 1/4 of an inch to two inches in diameter, twist drills increase by sixty-fourths. Considerable study has been given the twist drill as to shape of point, size and angle of groove, angle of cutting edges, and clearance. There are a few other kinds of drills such as the flat, farmer, three-lipped, and four-lipped drills. These are not much used and a description of them will be omitted, but the twist drill will be fully described as it is extensively used in all kinds of work.

*Ideal Twist Drill.*—Figure 38 shows an ideal twist drill. To get the maximum efficiency from a drill, three things are essential in the grinding of it: First, equal *angles* of cuting edges; second, equal lengths of cutting edges; and third, the proper clearance. The proper angle is 59° with the center as shown at a, Figure 38. If the angles are different, that is one side with one angle and the other side with another angle, the result is that one lip is in advance of the other and does practically all the work and a true hole is not obtained. If the angles are the same, but one lip longer than the other, the drill is not ground centrally and the result will be a hole larger than the drill. The third important thing is the clearance. For general work this should be 12° as shown at b, Figure 38. Clearance is sometimes called "backing off."

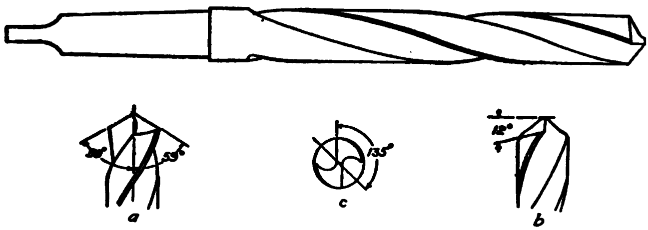


Fig. 38.—Twist Drill.

Experience shows that 12° is about the best angle at the outside diameter of the drill for general shop work.

This angle, however, should be gradually increased as the center of the drill is approached until the line across the center of the web stands at an angle with the cutting edges of about 135° as shown at c, Figure 38. For a heavy feed in soft material the angle of lip clearance may be increased to 15° at the outside diameter, but care should be taken that the angle at the center is given a corresponding increase. If sufficient angle of lip clearance at the center is not given, there is a tendency to split the drill up the web.

Again, if there is not sufficient clearance at the point of the drill, it takes more power to feed the drill.

**Angle Gauge.**—Figure 39, a, shows a gauge for testing the angle of a drill when grinding. It also has a rule for measuring the length of the lips. Figure 39, b, shows a way of testing to see if both lips are ground alike, but does not give the angle. By placing the point of the drill against something flat and holding a rule along the side of the drill, noting the dimension from the flat surface to the edge of

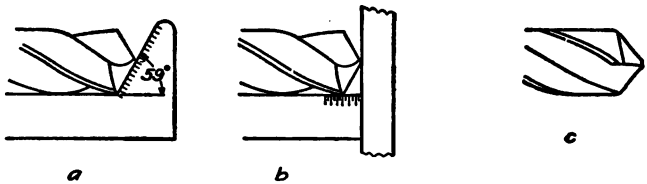



Fig. 39.—Angle Gauge.

the drill lip, and then by reversing or turning the drill half way around and measuring again the distance from the flat surface to the edge of the drill lip, it is obvious how the length of lip and equal angles are tested, but the angles are not necessarily correct.

In drilling brass or any thin material where the drill goes through, it is best to grind the cutting edge parallel to the axis of the drill; in other words, to grind away the rake given to the drill by the twisted groove. This will lessen the tendency for the drill to draw into the work when going through the hole which is being drilled. Figure 39, c, shows how this grinding is done.

*Grooves.*—The purposes of the grooves in a twist drill are first for letting the chip out and second for letting oil in. Some drills are provided with oil tubes to carry the oil to the point of the drill. A drill can be used on a lathe, a drill press, a boring mill, or a milling machine. The *twist* or *spiral* groove in drills is for the purpose of giving rake to the cutting edge. This rake should be the same at all points of the drill as it is ground away. In what is called the "increase twist," this angle of rake varies a little, but in what is called the "constant angle," it is always the same.

*Increase Twist.*—What is meant by "increase twist"? To maintain sufficient strength and to resist the torsional strain to which a drill is subjected in use, without its being so thick at the point as to require excessive force to make it penetrate the work, it is the custom to make the grooves of gradually decreasing depth from the point to the shank. This naturally makes the area less near the shank than at the point and if no means were employed to increase this area, the tendency would be for the chips to clog in the grooves. In the "increase twist" drill this difficulty is overcome by gradually increasing the forward traverse of the drill while it is fed to the milling cutters which cut the grooves, the speed of rotation of the drill remaining unchanged. Through the ensuing change in the angle of the milling cutter to the groove, the groove is made wider and its area thereby increased.

*Constant Angle.*—In the "constant angle" drill the speed of rotation of the drill is constant also. The traverse feed is constant, but a gradual variation of the angle of the cutters to the axis of the drill widens the grooves and in this way maintains an equal area.

of groove. By this means the efficiency of the cutting lip of the drill is not impaired at any point by changing the pitch of the groove.

**The Shank.**—The end which drives the drill is called the shank. The Morse taper shank has almost universally been adopted in the United States. Its taper is about ⅝ of an inch to one foot. The shank should fit in the socket or the sleeve properly. The tang at the end of the shank is for the purpose of driving the drill. The socket holds the drill true and also helps to drive it. Some makers put a double tang on their drills, others put a keyway in the shank which fits into a key in the socket for additional driving. In use sometimes, the tang breaks off. The drill must then be driven by the friction of the shank in the socket unless some other means are provided. As a remedy for this there has been invented what is known as a "use-em-up" socket. When the tang is broken off, a flat place is ground on the drill shank which will fit the flat key in the "use-em-up" socket.

*Socket and Sleeve.*—For holding drills in the drill press, the socket and the sleeve of different sizes are employed. A large drill will naturally require a larger shank than a small one. The spindle of the press has only one size but is capable of drilling large or small holes; therefore, something must be furnished to take care of the range of the press. This is accomplished by using different sized sockets or sleeves.

A socket is shown in Figure 40 and a sleeve in Figure 41. The difference is readily seen. The socket adds another sized shank to the drill which will fit the press and the sleeve bushes the press spindle so it will fit the shank of the drill. The slot shown is for the purpose of inserting the drift key to drive out the drill. A drift key is shown in Figure 42.

**Drilling Machines.**—The classification of drilling

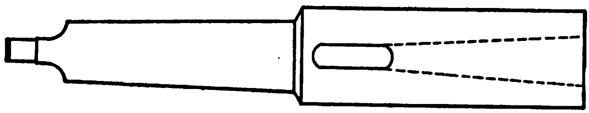


Fig. 40.—Drill Socket.

machines is: Vertical, Horizontal, Radial, Multiple, Spindle, Portable, Hand Electric, Hand Pneumatic, and the "Old Man and Ratchet."

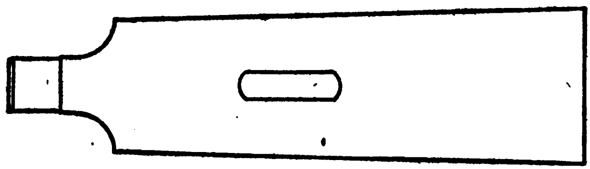


Fig. 41.—Drill Sleeve.

*Vertical.*—A vertical drill press is one in which the spindle is vertical and remains in one position, the table being capable of rotation on its own axis and

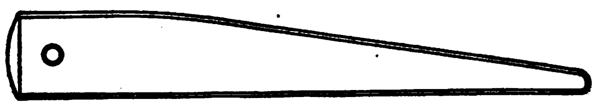


Fig. 42.—Drift Key.

this axis rotating around the column of the drill press. In this way any part of the work can be brought under the drill.

*Horizontal*—A horizontal drill press is one in which the spindle is horizontal, but can be moved up and down, also to right and left, for the purpose of bringing the drill to the place where the hole is to be drilled, whereby it is not necessary to move the piece which in the case of horizontal drill press work is generally large and heavy.

*Radial.*—A radial drill press is one in which the spindle can be moved in and out from the column of the press, also the spindle can rotate around the column, thereby bringing the drill to the place where the hole is to be drilled. Radial drill press work is also heavy.

*Multiple Spindle.*—A multiple spindle is a drill press which has a number of spindles, each one being capable of drilling a different hole at the same time. This press is for drilling duplicate parts which have several different sized holes to be drilled.

*Portable.*—The old style portable press was one which could be placed at any location in the shop to drill holes in work which might be too heavy or too large to be put under the press. It was generally driven by a rope drive situated at some convenient place in the center of the shop. Since the introduction of electricity any press which can be taken to the work and driven by electricity is called a portable press.

*Hand Electric.*—A hand electric drill is one driven by electricity and held in the hands. It is a portable press.

*Hand Pneumatic.*—A hand pneumatic drill is the same as the preceding except that it is driven by compressed air.

*Old Man and Ratchet.*—The "old man and ratchet" is a combination of a post which can be clamped to the work and an arm which has adjustments in all directions. This in connection with a ratchet is called "the old man and ratchet." This is illustrated in Figure 43.

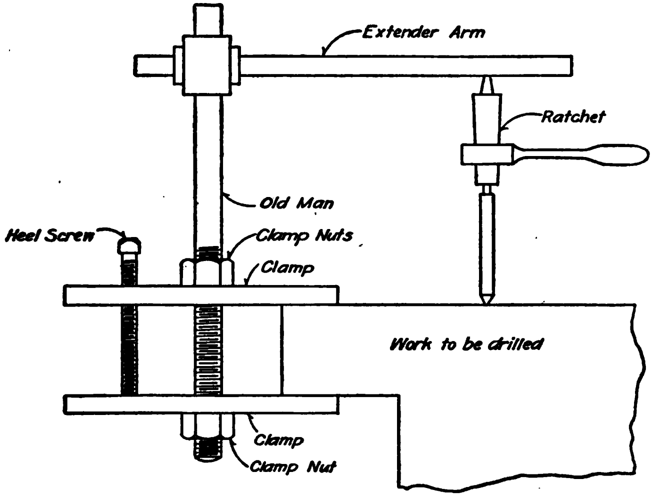



Fig. 43.—Old Man and Rachet.

*Principal Parts and Their Uses.*—In Figure 44 is illustrated a simple drill press with the principal parts named. The different drilling tools are drill, reamer, countersink, counterbore. The different drilling operations done on a drill press are drilling, reaming, countersinking, counterboring, spot-facing, taping, and stud-driving. Boring with a bar is sometimes done on a drill press. Drilling is merely making a hole with a drill. Reaming is making a drilled hole smooth and to exact size with a reamer in the drill press. Countersinking is enlarging the end of a hole at an angle

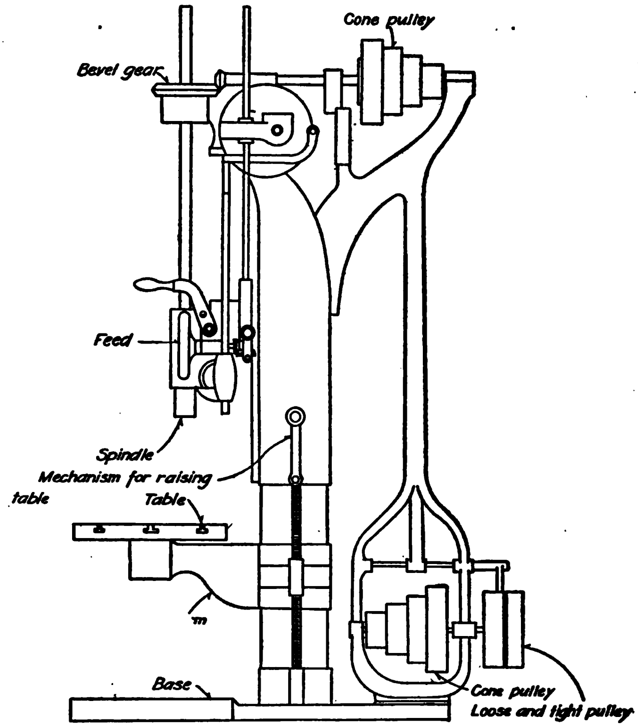



Fig. 44.—Drill Press.

to itself. Counterboring is enlarging the end of a hole parallel to itself. Spot-facing is counterboring carried far enough to give a true surface to the top of a hole for the purpose of giving a bearing to the head of a bolt or a nut. Taping is threading holes with a tap held in a chuck in the spindle of the drill press. Stud-driving is inserting studs in holes that have been taped.

**Methods of Drilling.**—When a hole is to be drilled it is laid off as shown at a in Figure 45. The center has been found and marked with a center punch. Around this center, a circular line has been drawn with the dividers and this line is marked with light punch

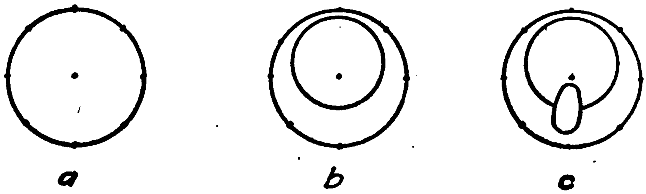


Fig. 45.—Examples.

marks for fear it may become erased. The drill is started directly over the center of the marked hole. After the drill has entered the metal it may do what is called "run" as shown at b in Figure 45. When the drill does this, it is necessary to "draw" it by using a gouge and making a groove, as shown at c in Figure 45. This grooving must be carried from the edge of the circle down to the center. Sometimes a little gouging in the center is enough to bring the drill to the proper place.

*Care in Starting.*—Care should be taken in starting the drill. It should be in the center of the hole to be drilled. If it is started with the drill in the center, there is less risk of the drill's running, but even if started in the center, there is no certainty it will stay there. An excellent way to assist it in keeping in the center is to drill a small hole first (which is not likely to run) and then to drill the large hole. The large drill will follow the small hole. In cases where holes are to be drilled very accurately care should be taken in holding the work. The table of the drill press is pro-

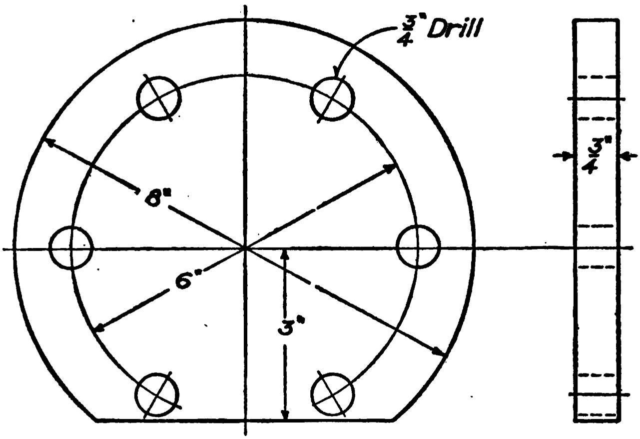



Fig. 46.—Exercise.

vided with slots for bolts and these should be used for fastening the piece to the machine.

*Exercise in Drilling.*—Figure 46 shows a drawing of a casting which is to be laid off and drilled.

*Reading the Drawing.*—The drawing shows that there are to be six ¾-inch holes drilled on a radius of 3 inches, these holes to be equally spaced and symmetrical on either side of the center. There is another condition which the drawing indicates, and this is that the centers of the holes on the horizontal line are parallel to the line which shows where a segment of the circle has been cut off.

*Laying Off.*—Find the center of the casting. Draw a line through the center parallel to the line showing where the segment has been cut off. With the dividers set to a three-inch radius, describe a circle around this center. As the number of holes are six, this three-inch radius can be used to step off the positions of the holes, starting from either intersection of the horizontal line and the circle which is around the center. When the six positions of the holes have been found, mark them with the center punch and with the dividers set to 3/8-inch radius describe circles around the points. These circles being light might become erased; therefore, it is better to prick-punch them in about four places.

*Drilling.*—The piece is now laid off and ready to be drilled. Procure two parallel strips about 3/4-inch thick and 8 inches long. Place them on the table of the drill press with the piece to be drilled on top of them. Be careful the parallels miss the holes to be drilled so that when the drill goes through, it will not drill into the strips. Clamp the piece to the table, placing the clamps over the parallels and proceed to drill the holes, observing the precautions of starting the drill over the center of the holes and drawing them if the drill runs. The parallels are used to avoid drilling into the table of the drill press.

**Drilling Jig.**—When there are a number of duplicate parts to be drilled, it is economical to use what is known as a drilling jig. Figure 47 shows a form of drilling jig for drilling a cylinder head. At a is shown the jig complete. The holes are laid off correctly and drilled about ¼-inch larger than the proper size, then bushed with hardened steel bushings to the exact size required. These bushings are to prevent the drill from wearing the hole and thereby spoiling it for the purpose it was intended, namely, to guide

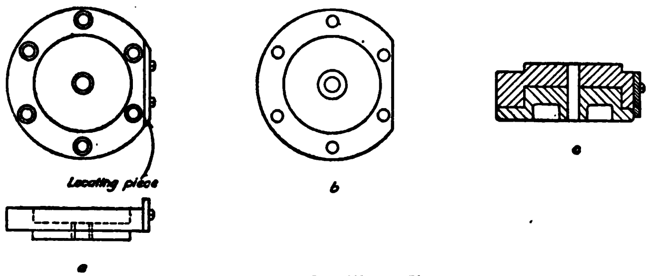



Fig. 47.—Drilling Jig.

the drill. As the holes are not equally spaced or on the same radius, it is necessary to have what is called a locating point or piece. For this jig this piece is shown at the right of the sketch. It fits along the line where the segment of the cylinder head has been cut off. At b is shown the cylinder head which is to be drilled with this jig and at c is shown a section of the jig and cylinder head assembled and ready for use.

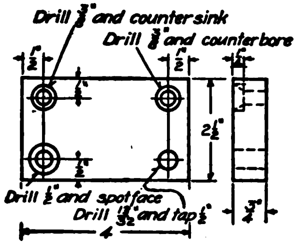
It does not pay to make a jig where only two or three pieces are to be drilled. The time required for making the jig would not justify the expense incurred.

## QUESTIONS ON CHAPTER III

1. What is the definition of a drill?
2. Give the names of some different kinds of drills.

3. What are three important things to be observed in grinding a twist drill?
4. To what angle with the center should the drill be ground?
5. If the angles of the lips are different what is the result?
6. How can a hole be made which is larger than the drill used?
7. Why is a drill given clearance? What is the clearance angle for general work?
8. What is the consequence if a sufficient angle is not given to the lip of the drill at the center?
9. How should the lip of a twist drill be ground for drilling brass?
10. For what purposes are the grooves in a twist drill?
11. On what machines can a twist drill be used?
12. What is meant by "increase twist" and by "constant angle"?
13. What is the driving end of a drill called?
14. What taper is generally given to the driving end?
15. When the tang is broken off, how can the drill be driven?
16. What is the difference between a sleeve and a socket?
17. Name four different kinds of drilling machines.
18. Name four different kinds of drilling tools and operations.
19. When a drill does not keep in the center when drilling, what is this action called?
20. How is this error corrected?
21. How are the circular lines around a center which is to be drilled preserved?
22. Why are parallels used on the drill press?
23. What is a drilling jig?
24. When is it not well to make a drilling jig?

## Exercises for Practice

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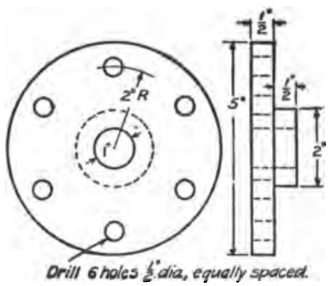


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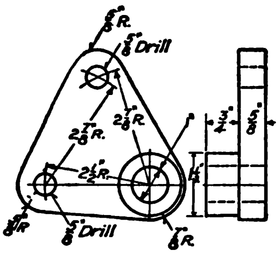


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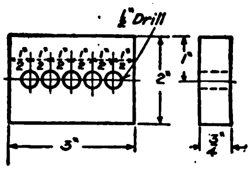


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# CHAPTER IV

## THE LATHE

**Early Lathes.**—The lathe, when first made, consisted of a frame made of wood with two centers mounted on it and a rest for holding the tool. To rotate the piece to be turned, a cord was given one or two turns around the piece. One end of this cord

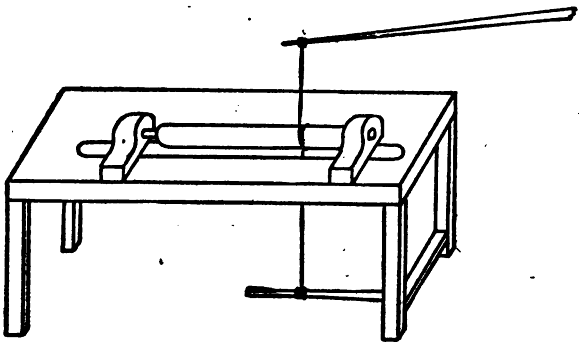


Fig. 48.—Old-Fashioned Lathe.

was fastened to a weight or treadle and the other to a lath; hence, the name lathe. The lath was made to spring up and down, making the piece revolve in two directions, but the cutting was done when the piece was revolving in the forward direction. A sketch of this lathe is shown in Figure 48. A lathe of this kind was good for turning only small pieces of wood.

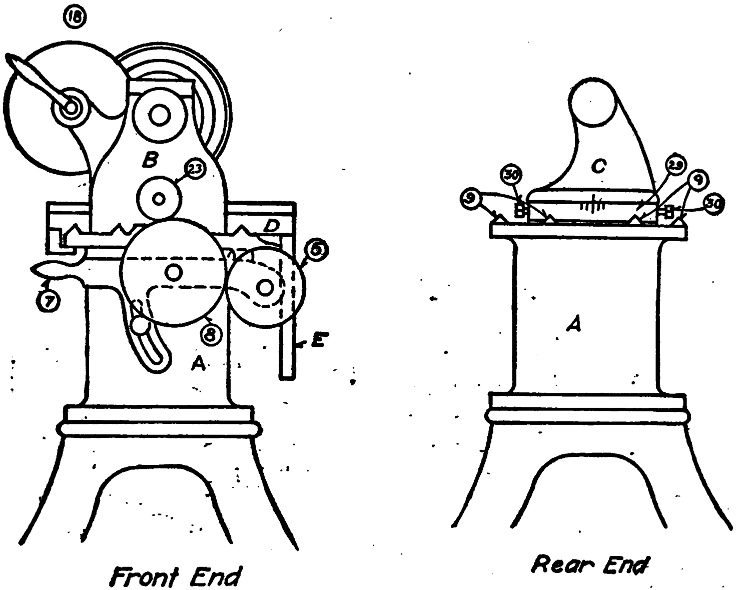



Fig. 49.—Modern Lathe.

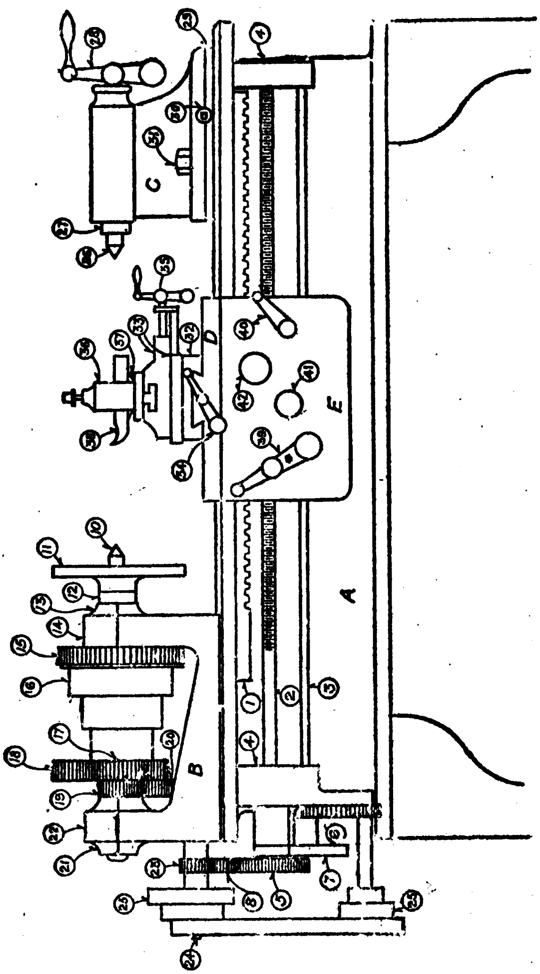


Fig. 49-A.—Modern Lathe.

| Principal Parts | List of Component Parts.— |
|---|---|
| **Bed—A.—** | 1—Rack |
| | 2—Lead screw |
| | 3—Feed rod |
| | 4—Bearings for feed rod and lead screw |
| | 5—Change gear on lead screw |
| | 6—Reduction gears for feed rod |
| | 7—Arm for change gear idler |
| | 8—Idler gear |
| | 9—Ways |
| **Head Stock—B.—** | 10—Live center |
| | 11—Face plate |
| | 12—Spindle |
| | 13—Front bearing |
| | 14—Front cap |
| | 15—Face gear |
| | 16—Cone pulley |
| | 17—Cone gear |
| | 18—Large back gear |
| | 19—Spindle gear |
| | 20—Tumbler gear |
| | 21—Rear bearing |
| | 22—Rear bearing cap |
| | 23—Change gear on stud |
| | 24—Stud |
| | 25—Cone pulleys for feed |
| **Tail Stock—C.—** | 26—Dead center |
| | 27—Tail stock spindle |
| | 28—Handle for actuating or moving tail stock spindle |
| | 29—Sub-base |
| | 30—Screws for adjusting tail stock |
| | 31—Clamping nut |
| **Carriage—D.—** | 32—Cross slide |
| | 33—Compound rest |
| | 34—Hand cross feed |
| | 35—Hand feed for compound rest |
| | 36—Tool post |
| | 37—Slipper |
| | 38—Tool |
| **Apron—E.—** | 39—Hand longitudinal feed |
| | 40—Split nut lever |
| | 41—Knob for engaging automatic longitudinal feed |
| | 42—Knob for engaging automatic cross feed |

**Foot Lathe.**—In time it became necessary to turn iron. It was then that the foot lathe came into existence. The foot lathe was more elaborate than the former, and was built of iron instead of wood. An endless belt was employed to drive the spindle, thereby giving a continuous rotary motion in one direction to the piece being turned. At first, a hand tool and rest was used, but in time the slide rest was invented which held the tool rigid.

**Engine Lathe.**—As time went on and there was a demand for still more accurate work, the engine lathe was produced. The engine lathe, being driven by some kind of engine, received the name engine lathe to distinguish it from the foot lathe. At the present time, an engine lathe is one which is provided with the following equipment: Bed, head stock, tail stock, carriage apron, lead screw, and feed mechanism.

A sketch of a simple lathe is shown in Figure 49-A. The principal parts are marked A, B, C, D, E. The component parts of these are marked 1, 2, 3, etc.

**Detailed Analysis.**—In order to become better acquainted with the names of the various parts of the lathe, a study of Figure 49-A will prove valuable to the beginner. By referring to the numbered list, the names of the different pieces can readily be learned, and as there are only forty-two (42), it would not be a very hard task to memorize at least the majority of them. It must not be inferred from this that there are only forty-two (42) parts to this lathe, but forty-two (42) cover a large number of the principal parts. In fact, this lathe, including one of every different kind of screw, has two hundred and forty-two (242) parts.

**Bed.**—The bed, A, is a casting, well ribbed to give it stiffness. It is planed where the legs are fastened to it, also on the top where the head stock, tail stock, and carriage rest. The angular projections on the top of the bed are called the ways. The ways should be straight and fit the parts perfectly which slide or rest on them.

1. *Rack.*—This is for the purpose of giving motion to the carriage either by hand or by the power feed. It is generally made of steel with teeth of the proper pitch for the size of the lathe. When threading, the rack does not move the carriage but is rather a hindrance. To overcome this, the rack pinion is constructed so it can be disengaged from the rack when threading.

2. *Lead Screw.*—This is made of machinery steel with a thread on nearly its whole length. It moves the carriage when cutting threads, by means of a split nut which is secured to the apron of the lathe. Sometimes the lead screw and the feed rod are one and the same, the lead screw having a keyway to drive the feed mechanism in place of the feed rod which in this case is omitted. In precision lathes, the lead screw is never used for a feed rod, as it might become worn in some places more than in others and might thus impair the accuracy of the screw. The lead screw is always driven with gears which are called change gears. These change gears give different ratios of speed between the spindle of the lathe and the lead screw when cutting threads.

3. *Feed Rod.*—It is also made of machinery steel with a keyway cut nearly its whole length. This rod gives motion to the feed mechanism on the apron for

both cross and longitudinal feeds. It is generally driven by cone pulleys and a belt, but when heavy feeds are required, gears are sometimes employed.

4. *Bearings for Lead Screw and Feed Rod.*

5. *Change Gear for Lead Screw.*—This with the change gear (23) will be explained more fully later, under the head of Thread Cutting.

6. *Reduction Gears for Feed Rod.*—These gears are employed to give the proper speed to the feed rod and also to make room for the change gear of the lead screw.

7. *Arm for Change Gear Idler.*—As the change gears are of different sizes, the idler which transmits motion from the gear on the stud to the one on the screw, must be capable of being placed in different positions. With this arm, by means of the radial and straight slots, it is possible to place the idler in any required position.

8. *Idler Gear.*—This gear transmits motion from the stud gear to the lead screw gear.

9. *Ways.*—These are generally planed to an angle of 80° or 90°. Sometimes there is one angular way on one side and a flat way on the other. The latter form furnishes a stiffer and better wearing support for the carriage.

**Head Stock.**—The head stock, B, is made of cast iron and is clamped to the two middle ways of the bed.

10. *Live Center.*—This is made of tool steel. Sometimes it is hardened and sometimes it is left soft so it can be readily trued up. The included angle of the point should always be 60°. This center is given the name live center because it rotates or moves with

the spindle to distinguish it from the dead center in the tail stock which does not move.

11. *Face Plate.*—This is made of cast iron. Its function is to drive the dog when a piece is being turned between the centers and also to clamp work to it which cannot be turned on the centers. The chuck occupies the same place on the lathe when the face plate is removed.

12. *Spindle.*—This is the most vital part of the head stock. On its alignment and truth depends largely the degree of accuracy with which the work of the lathe can be done. In the best lathes it is made of crucible steel and is ground after it is turned. If it is not in line with the ways when turning or boring a piece in the chuck or face plate, the piece will be tapered, not straight. If it is not round this error will be transmitted to the piece of work being done. Again, if the spindle is not round, it will chatter in is bearings and this chatter will be transmitted to the work. If it is too light, it also causes chatter.

13 and 21. *Front and Rear Bearings.*—These are sometimes made of bronze. Cast iron lined with babbitt metal or some good bearing composition is often used. Cast iron alone has been used and gives very good results.

14 and 22. *Front and Rear Caps.*—These need no explanation, as it is evident they hold the bearings in place.

15. *Face Gear.*—This is a large cast-iron gear which is keyed to the spindle. It can be fastened to the cone which is loose on the spindle, thus making the cone and spindle practically one piece, so that high speeds can be obtained when not using the back gear.

16. *Cone Pulley.*—The purpose of this pulley is for getting different speeds both with and without the back gear. It is made of cast iron and runs loose on the spindle, but can be made tight to the spindle by fastening it to the face gear. The method of fastening is by either a sliding bolt or a pin. This will be explained fully later in the description of the internal parts of the head stock, Figure 50.

17. *Cone Gear.*—This gear is keyed to the small end of the cone. It is the first gear in the back gear train.

18. *Large Back Gear.* This is the second gear in the back gear train. A small gear in the same sleeve with this gear is the third and the face gear is the fourth in the back gear train. These will be explained also under the head of internal parts of the head stock, Figure 50.

19. *Spindle Gear.*—This is a small gear which is keyed to the spindle and gives motion to the stud. The stud drives both the feed rod and the lead screw.

20. *Tumbler Gear.*—There are two of these. The other one is just back of the one shown at 20. The rotation of the stud is reversed by means of these gears for both feeding and thread cutting.

23. *Change Gear on Stud.*—This is the first gear in the train for cutting threads. The idler is the second gear and the gear on the lead screw is the third. The first and the third gear in the train can be changed, hence the name change gear is given to them.

24. *Stud.*—The stud generally has the same rate of speed as the spindle. Sometimes it runs at only one-half the spindle rate. The spindle could take the place of this stud if it were not necessary to reverse the

motion of both the feed rod and the lead screw while the spindle is revolving in the same direction. Therefore, the stud is introduced to accomplish the reversing of the feed rod and lead screw.

25. *Cone Pulley for Feed.*—The upper one is secured to the stud by a feathered key. It drives the lower cone through a belt. The steps on the cones make it possible to obtain different ratios between the stud and feed rod for different rates of feed.

**Tail Stock.**—The tail stock, C, is made of cast iron, but is not quite so rigid as the head stock, because it is not required to do so heavy duty.

26. *Dead Center.*—Like the live center, this is made of tool steel, but is always hardened because the work revolves on it, not with it, as in the case of the live center. The included angle of its point should be 60°, the same as that of the live center.

27. *Tail Stock Spindle.*—This is made of machinery steel. It has a tapered hole in the forward end to receive the dead center. At the back end there is a bronze nut to receive the screw for running it in and out when putting pieces of work between the centers. It is provided with a keyway to keep it from turning.

28. *Handle for Moving Tail Stock Spindle In and Out.*—This handle is keyed to the screw which gives the in and out motion to the spindle of the tail stock.

29. *Sub-base.*—For turning tapers and making perfect alignment of the tail stock with the head stock this sub-base is provided. The tail stock proper can be moved backward and forward by means of the adjusting screws shown at 30.

30. *Adjusting Screws.*—These are for centering the tail stock.

31. *Clamping Nut for the Tail Stock.*

**Carriage.**—The carriage, D, is made of cast iron and is fitted to the outside ways of the lathe bed. The carriage is capable of moving backward and forward on these ways to feed the tool to the work.

32. *Cross Slide.*—This is made of cast iron. It has what is called a dovetail planed on it to keep it in a straight line when being fed across the carriage.

33. *Compound Rest.*—This is composed of two pieces, the base which swivels on the cross slide and a sliding piece which carries the tool on top of this base. This base can be swiveled to any angle and the compound rest slide is fed in and out by means of the hand feed shown at 35. With the compound rest, short steep tapers can be turned or bored. The compound rest is also convenient for turning up the centers of the lathe.

36. *Tool Post.* This is always made of steel. The clamping screw should be case-hardened or made of tool steel and tempered, as there is considerable wear on it. The tool post is capable of turning around and moving to and fro in the tee slot of the compound rest, thus enabling tools to be put in it at any angle or position which the work in hand may require.

37. *Slipper.*—This is a very important part of the tool post. With it one is able to raise or lower the point of the tool in order to bring it to the proper position in relation to the center of the lathe. The bottom of this slipper is convex and fits into the concave part of the tool post ring. The top where the tool rests is straight. By slipping it to the right, the point of the tool is lowered; and by slipping it to the left the point is raised.

38. *A Form of Round Nose Cutting Tool.*

**Apron.**—The apron, E, is made of cast iron and is secured to the carriage by means of screws. It carries the mechanism for the hand feeds, the automatic feeds, and the split nut for screw cutting. Sometimes the reverse feed is placed on the apron. When this is done a neutral point is provided so that the feeds can be thrown out when cutting threads.

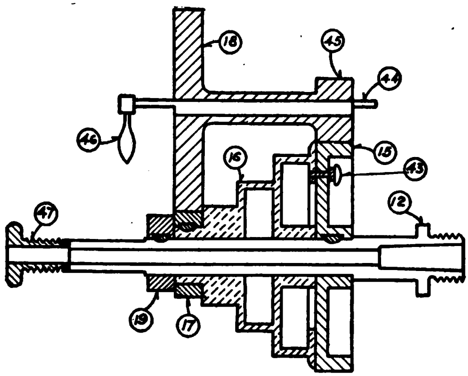


Fig. 50.—Head Stock.

39. *Hand Feed Handle.*—This moves the carriage longitudinally by hand.

40. *Lever for Engaging the Split Nut.*

41. *Knob for Engaging the Longitudinal Automatic Feed.*

42. *Knob for Engaging the Automatic Cross Feed.*

**Internal Parts of the Head Stock.**—For a better understanding of the construction of the head stock, a study of Figure 50, where a horizontal sectional view is shown, will be of some assistance. The parts shown here have the same numbers as in Figure 49. Added parts, not shown in Figure 49, are marked by a continuation of the same set of numbers beginning at 43.

43. *Pin.*—This is for disengaging the cone from the face gear.

44. *Eccentric Shaft.*—This is used to throw the back gears in and out of mesh with the face gear and the cone gear.

45. *Small Back Gear.*

46. *Handle for Rotating Eccentric Shaft.*

47. *Adjusting Screw for End Thrust.*

**Back Gear Out.**—The face gear, 15, is keyed to the spindle, 12. The cone pulley, 16, runs loose on the spindle. The cone gear, 17, is keyed to the cone. When the pin, 43, is in the position as shown and the handle, 46, is thrown back to the opposite position, the lathe spindle will revolve at the same rate as the cone. This is called "back gear out."

**Back Gear In.**—The cone, 16, is disengaged from the face gear, 15, by pulling out the pin, 43, and thus allowing the cone to rotate free on the spindle. The cone gear, 17, with (say) thirty teeth is secured to the cone and revolves with it. The cone gear meshes with large back gear, 18, when it is thrown in, having (say) eighty teeth. The large back gear and the small back gear, 45, rotate together. The small back gear of (say) twenty teeth meshes with face gear, 15, of (say) ninety teeth and, since the face gear is keyed to the spindle, the latter is driven by the cone through this chain of gears, namely, 17, 18, 45, and 15. If it is assumed that the cone is running fifty revolutions per minute, putting in the back gear reduces the speed of the spindle by the amount of the ratio of the back gear; thus:

$$\frac{30}{80} \times \frac{20}{90} = \frac{1}{12}, \text{ or } \frac{1}{12} \times \frac{50}{1} = 4\frac{1}{6}.$$

Therefore, the spindle with the back gear in, will revolve 4 1/6 revolutions, while the cone is revolving fifty revolutions per minute.

*Slow Speeds.*—Slow speeds are necessary for turning large diameters. If a piece 12 inches in diameter is to be turned and the back gear is not thrown in, but the cone speed used, the peripheral speed of the piece will be about 150 feet per minute which is too fast for steel unless a very good grade of high speed steel is used for the cutting tool. Again, with the back gear in, the speed will be only about 12 feet per minute, which is too slow, but this can be remedied by increasing the cone speed.

*Spindle.*—The spindle is hollow, allowing the stock to pass through it for the convenience of working. Another purpose of the hollow spindle is for knocking the center out. The spinde gear, 19, is keyed to the spindle. This gear, in connection with the change gears, makes it possible to obtain certain ratios between the spindle and the lead screw when cutting threads. The end thrust of the spindle is taken care of by the adjustable nut shown at 47.

## QUESTIONS ON CHAPTER IV

1. Give the names of the principal parts of an engine lathe.
2. From what material are these principal parts made?

3. What name is given to the angular projections on the top of the bed?
4. What part of the lathe gives the longitudinal motion to the carriage when cutting threads?
5. On what kind of lathe is it not advisable to have the lead screw and feed rod one? Why?
6. How is the feed rod generally driven?
7. What is the idler gear on a lathe?
8. Why is the center in the head stock called the live center?
9. What is the included angle of the points of the lathe centers?
10. For what purpose is the face plate?
11. What part of the head stock is the most vital? Of what is this part made?
12. Of what material are the bearings of a lathe made?
13. Why is a lathe provided with a cone pulley?
14. For what purpose is the stud on a lathe?
15. Why is the tail stock made adjustable across the ways?
16. To which set of ways is the carriage fitted, the inside or the outside?
17. What kind of tapers can be turned with the compound rest?
18. For what is the slipper on the tool post?
19. Why is it necessary to have different spindle speeds on a lathe?
20. For what reason is the spindle of a lathe made hollow?

# CHAPTER V

## STRAIGHT TURNING

**Feeds.**—While turning in the lathe, the tool is fed to the work either along or across the ways by means of the carriage and the cross slide. This can be done either by hand or automatically. The hand feeds are used for the former and the automatic feeds for the latter. For a fuller understanding of how the automatic feeds work, reference is made to Figure 51, where an arrangement of the hand and automatic feeds is shown in an illustration of the apron. Also, the split nut for screw cutting. The different parts are numbered 1, 2, 3, etc. A list of these with their names is given below.

**Parts of the Automatic and Hand Longitudinal Feed.**

1. Feed rod.
2. Worm.
3. Worm wheel.
4. Friction ring.
5. Cam for engaging friction ring to worm wheel.
6. Knob for operating cam.
7. Worm pinion.
8. Rack gear.
9. Rack pinion.
10. Knob for pulling out rack pinion.
11. Handle for hand feed.
12. Pinion for hand feed.

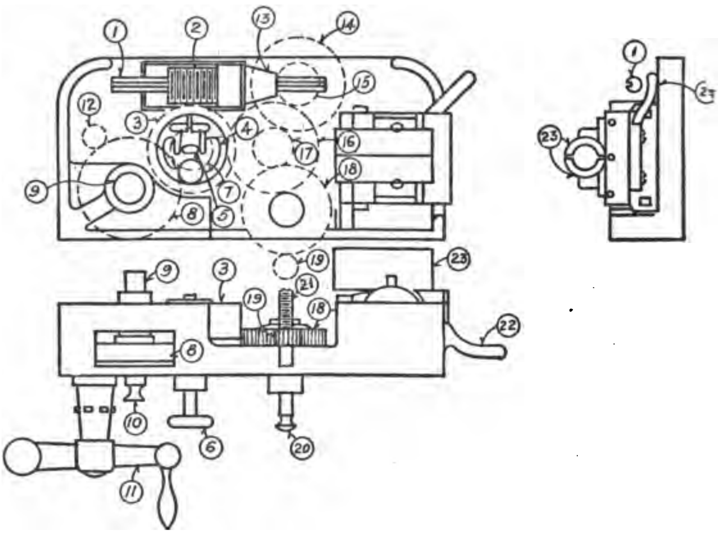



Fig. 51.—The Apron.

## Parts of the Automatic and Hand Cross Feed.

13. Bevel pinion.
14. Bevel gear.
15. Spur gear pinion keyed to bevel gear.
16. Large compound gear.
17. Small compound gear.
18. Sliding gear.
19. Pinion keyed to cross feed screw.
20. Knob for engaging sliding gear.
21. Feed screw for cross feed.
22. Handle for opening and closing split nut.
23. Split nut.

## Description of the Preceding Parts.

1. *Feed Rod.* This rotates the worm by means of a key in the worm and the keyway in the rod which extends nearly the whole length of the rod.

2. *Worm.*—The worm drives the worm wheel.

3. *Worm Wheel.*—The worm wheel can be locked to the worm pinion through the friction ring which carries this pinion.

4. *Friction Ring.*—This only rotates when clamped to the worm wheel.

5. *Cam.*—By turning this cam to the position indicated the friction ring is locked to the worm wheel by spreading the fingers as shown in the sketch. When in any other position the friction ring is not locked.

6. *Knob.*—This is for engaging and disengaging the cam.

7. *Worm Pinion.*—This is one with the friction ring and rotates when it does.

8. *Rack Gear.*—This gear is keyed to the rack pinion by a sliding key and transmits motion from the worm pinion to the rack pinion. It also transmits motion from the handle to the rack pinion through pinion 12 when the hand feed is used.

9. *Rack Pinion.*—This meshes in the rack and in conjunction with the rack gear and with either the automatic or the hand feed gives motion to the carriage.

10. *Knob.*—On the end of the rack pinion a knob is provided for pulling the pinion out of mesh with the rack when cutting threads.

11. *Handle for Hand Feed.*—This is keyed to the shaft of pinion, 12, for hand feed only.

12. *Pinion for Hand Feed.*—This pinion is for transmitting motion from the handle, 11, to rack gear when feeding by hand.

**Action of Parts.**—The work done by these parts from the feed rod to the rack pinion is as follows:

*Longitudinal Feed.*—The feed rod rotates the worm. The worm revolves the worm wheel continually while the feed rod is in action. The automatic feed is now engaged. The worm wheel by means of its pinion gives motion to the rack gear and the rack gear gives motion to the rack pinion which in turn gives motion to the carriage. If the rack pinion is pulled out when either the automatic or hand feed is used, the carriage will stand still. It should only be pulled out when the screw is moving the carriage, that is, when cutting threads. When cutting threads it is better to have it out because then, even if the feed is engaged, the screw can pull the carriage along and is not affected by the feed as would be the case if the screw were pulling the carriage at one rate and the feed trying to pull it at another rate of speed.

*Cross Feed.* The action of the cross feed is slightly different from that of the longitudinal. The bevel pinion, 13, in Figure 51 is driven by the feed rod. This pinion drives the large bevel gear, 14, to which is fastened the spur gear, 15; therefore, 14 and 15 revolve together at the same rate of speed. 16 and 17 are large and small compound gears which are fastened together and rotate at the same speed, 16 receiving its motion from pinion 15. These five gears rotate all the time while the feed rod is in motion, but do not give motion to the cross feed until the sliding gear, 18, is pulled into mesh with gears 17 and 19. The sliding gear is shown engaged in the sketch.

*Reversing the Stud.*—When feeding or screw cutting, the carriage must be capable of moving in either direction. A change in the direction of motion of the feed mechanism must be provided for. This is usu-

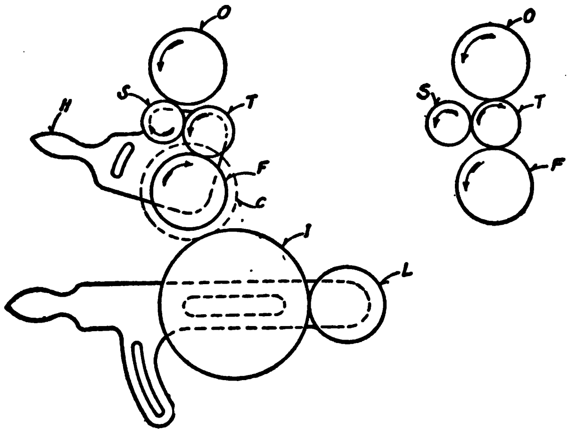



Fig. 52.—Reversing Gears.

ally accomplished by the arrangement shown in Figure 52. The four gears O, S, T, and F accomplish the reversing of the stud. O is the spindle gear, S is the first tumbler gear, T the second tumbler, and F the gear on the stud. These gears are all placed inside the head stock.

If O is rotating in the direction of the arrow, S will rotate in the opposite direction, T in the opposite direction to S, and F in the direction opposite to T, also opposite to the spindle gear O. This arrangement will drive the stud in one direction.

*Reversing the Feed.*—If the handle, H, which swivels around the axis F, is thrown down, it will carry gear T into mesh with O and at the same time carry gear S out of mesh with O. With O, T, and F meshed together, as shown in the sketch to the right, it is evident the direction of F will be reversed. In the second arrangement gear S is inoperative.

There is another method of reversing the feed only;

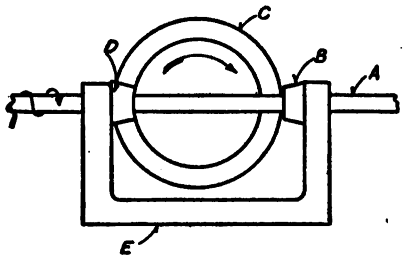



Fig. 53.—Feed Reverse.

this is shown at Figure 53. The two bevel pinions are carried by a frame E. This frame can be moved longitudinally to engage either B or D with the large bevel gear C. This gear C transmits motion to the train of feed gears for both longitudinal and cross feed. When meshed as shown, with feed rod revolving in the direction of arrow, large gear C will revolve in the direction shown, or clockwise. If frame E is pushed to the left, it will disengage D and engage B, which will reverse the motion of C. This device can only reverse the feed. It is not possible to reverse the screw with it.

The first method, that of reversing the stud, will reverse both feed and screw and is the better.

*Idler*.—Again in Figure 52, the first change gear C is on the stud with F (it is shown in dotted line). To give motion to gear L on lead screw, the idler I is employed. This idler can be placed in any position by means of the slots in arm R. In this way motion is communicated from the first change gear to the lead screw for any ratio that may be required.

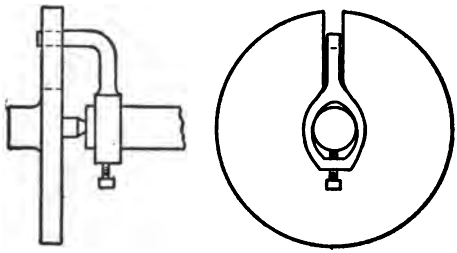


Fig. 54.—Lathe Dog.

**Work Between Centers.**—*Dogs*.—When turning a piece of work between the centers, a dog is used to connect the work with the spindle of the lathe, also to drive the piece being turned. There are several different forms. The most common form is shown in Figure 54. The part which enters the slot of the face plate is called the tail. If it is bent, the name bent tail is given to it. If straight, it is called a straight-tailed dog. When a piece has been finished on one end and has to be turned around in the lathe with the dog clamped to the finished part, a piece of brass or copper should be put under the point of the set screw to keep it from marring the finished part. A split ring extending all the way around the piece is better.

*Face Plate Driver.*—Some work done between the centers does not require a dog to drive it as a face plate driver will engage some part of the work, for example, in the case of a pulley on a mandrel. A face plate bolt extending out to one of the arms of the pulley will drive it better than a dog. Two bolts placed diametrically opposite are still better if both bolts drive.

**Work Not On Centers.**—Work which cannot be done on the centers is either bolted to the face plate or held in a chuck. Some work requires a center or steady rest, one end of the work being supported and driven by the chuck, the other being held in the steady rest. Again, one end can be clamped to the live center by means of what is called a saddle or clamp.

Another kind of work is known as carriage work. Here the work is bolted to the carriage and operated on by a rotating cutter.

Chuck and face plate work covers a wide range of operations upon work which is rigidly secured to the live spindle.

*Chucks.*—Chucks are classified as independent, universal, and combination. The independent generally has four jaws, each jaw being operated independently by a screw. Sometimes these jaws can be reversed for the purpose of taking in larger diameters. The universal chuck is usually a three-jawed chuck. In this style of chuck the jaws all move together. The mechanism of this chuck consists of a scroll geared to three pinions, each pinion having a square on its hub to receive a wrench to open or close the jaws.

In the combination chuck both the independent and the universal characteristics are involved and by a slight adjustment it can be changed from one to the other. The universal and combination chucks are convenient for some work, but are only true for a short time. They soon become worn and should not be relied on for exact centering. For general every-

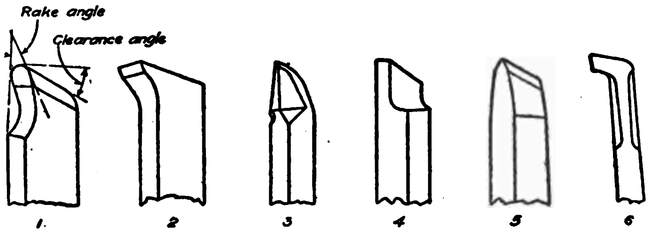



Fig. 55.—Turning Tools.

day work, the independent four-jawed chuck is the best.

**General Turning Tools.**—Before attempting to do any turning, a description of the general turning tools will be necessary.

1. Roughing tool.
2. Finishing tool.
3. Side tool.
4. Parting tool.
5. Threading tool.
6. Boring tool.

In Figure 55 a sketch of six different tools is shown. No. 1 is a round-nosed roughing tool for general work. No. 2 is a finishing tool. No. 3 is a right-hand side tool for facing the ends of cylindrical work. It is also made for the left hand. No. 4 is a parting tool, sometimes called a cutting-off tool. No. 5 is a threading tool for cutting threads. No. 6 is a boring tool for boring holes.

**Rake and Clearance.**—Cutting and turning tools have what is called *rake and clearance*. These are generally known as the angle of rake and the angle of clearance and are shown at No. 1, Figure 55.

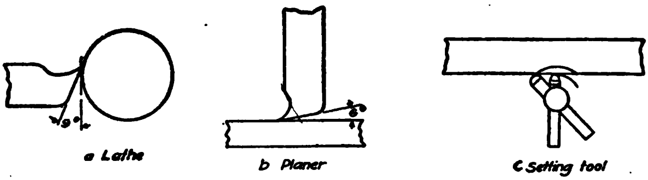



Fig. 56.—Clearance Angles.

*Angle of Clearance*.—The angle of clearance must be greater for a lathe tool than for a planer because, when turning, the point of the tool is set above the center and the piece being round, more clearance is required, while on the planer, the surface being worked is a plane and less clearance is necessary. This is illustrated at a and b, Figure 56.

The angle of clearance for a lathe tool should be about 9° and for a planer about 6°. To avoid spring, a tool should always be clamped in the tool post as near the cutting point as possible. It should be set at right angles to the axis of the work, thus avoiding the possibility of the tool's being drawn into the work. At c, Figure 56, this is illustrated.

**Straight-Turning Job.**—A simple straight-turning job is shown in Figure 57. This is to be made of a cast-iron bar 2⅛ inches in diameter and 15 inches long. This bar has been cast on end. One end is smooth and regular, while the other is rough, having been used as a sinking head for the casting.

*Cutting the Bar.*—The first operation will be to cut this bar to the proper length required by the drawing, namely 11½ inches long. It is only necessary to cut off the rough end, the other end can be faced in the lathe after the piece is centered. Some

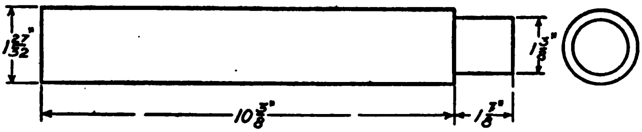



Fig. 57.—Turning Exercise.

allowance should be made in cutting this bar to length as the saw may not run true. Between ⅛ and ¼ inch will be enough to allow. The bar, when the end is cut off, should be about 11 11/16 inches long.

*Locating the Center.*—The next step is properly to locate and form the center. This can be done by eye, but better by using either the center square or hermaphrodite. The center should be carefully located in the average center of the bar so that the cut will be the same depth at all points as much as possible. If the first cut is eccentric, this eccentricity will be maintained but in a less degree and, unless several cuts are taken to eliminate this eccentricity, the piece will not be round.

*Drilling and Reaming the Center.* After it is located, the center should be marked with a center punch, then drilled and reamed. The drilling and the reaming can be done at the same time with what is known as a center drill. The center should be like a, Figure 58. The parallel hole which is drilled somewhat deeper than the angular part of the center, allows the point of the lathe center to penetrate the work when the work center wears. If the work center were only an angle which just fitted the lathe center, when the center became worn, most of the wear would be on the large diameter, not on the point, and the

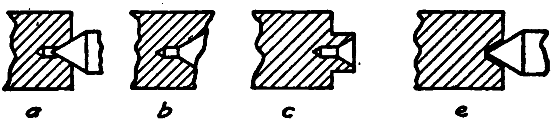



Fig. 58.—Centering.

center would be like e, Figure 58. With this condition the point of the lathe center would not fit and the piece would do what is called "ride on the center." It is evident that with the center as shown at e, it would be impossible to turn the piece cylindrically.

*Testing Alignment.*—The next step will be to ascertain if the centers of the lathe are in line. This can be done approximately by bringing the tail stock center to the head stock and noting if the points meet or are in line with each other across the ways. The alignment up and down is made when the lathe is built and does not wear an appreciable amount even after long service.

If the points are out of line they can be adjusted by means of the adjusting screws in the sub-base of the tail stock. The dog can now be secured to one end of the piece and the piece can be placed between the centers. Be sure to oil the dead center.

*Facing the Ends.*—The piece is now ready to be faced on the ends to the proper length, 11½ inches. The facing of the ends should be done before any turning is done on the diameter. The center in the shape as shown at b, Figure 58, should never be used when turning the diameter of a piece. This center is not symmetrical, one side is heavier as it contains more metal or bearing than the other. The light side will wear more when the tool is cutting and cause the center to become out of round. Facing the ends will correct such a center as this.

If, when facing the piece to the proper length, it leaves the center as at *c*, Figure 58, this projection should be cut off and the end re-centered. A center like c will be weak and break off easily.

*Rough Facing the Ends.*—The roughing tool, No. 1, can be used to rough face the ends. It will have to be set at an angle to do this, and will leave a projection at the center. This projection can be removed and the final finishing of the end done with the side tool, No. 3, which should be run in as far as possible in order to leave the end of the piece a perfect plane, at a right angle to the axis of the piece.

*Roughing Cut.*—The piece is now centered and has the right length. A roughing cut should be taken over the piece as closely as possible to the dog, leaving the diameter about 1/16-inch larger than the finished size.

*Test for Parallelism.*—The alignment of the centers was done approximately before any turning was done. After the roughing cut has been taken, test the piece with the calipers for parallelism. If both ends of the cut have the same diameter, the alignment is correct. If the end near the tail stock is larger than the other end, it shows that the tail stock must be moved towards the front of the lathe, because more metal must be taken off this end to make it of the same size as the other. If the end near the tail stock is smaller, the reverse movement of the tail stock must be employed. If, after making these corrections and taking a fine cut over the piece, both ends have the same diameter, the alignment is correct, and the piece can be turned to within 1/32-inch of the finished size.

*True Live Center.*—If the live center does not run true, when the piece is reversed between the centers, the turned parts will be eccentric with each other. It is, therefore, essential that the live center runs true.

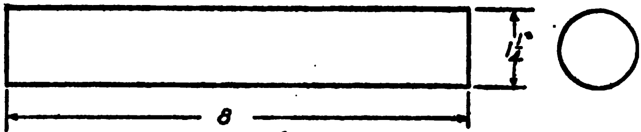
*Reversing the Piece.*—The piece should now be reversed end for end between the centers; and the part, where the dog was, should be turned to the same diameter as the rest. The dog must be put on the turned part. In the drawing, one end is shown turned down to 1⅜-inch diameter and 1⅛ inches long. This should now be done. The distance, 1⅛ inches, can be marked on the piece with the hermaphrodite; or the rule can be held on the piece when the first cut is running up, the feed being disengaged when the tool has traveled a little short of the 1⅛ inches.

*Finishing Details.*—When the roughening of this part is completed, the corners of the shoulder will be round. They should be square and can be made so with the square nosed tool, No. 4. With this same tool a light finish cut can be taken over the 1⅜-inch diameter. The next step will be to reverse the piece again in the lathe, to put the dog on the small end just finished, and to take the finishing cut on the rest of the piece.

## QUESTIONS ON CHAPTER V

1. How is the tool fed to the work when turning in the lathe?
2. What is the part of the machine called that gives motion to the worm?
3. How is the friction ring locked to the worm wheel?
4. Why is the rack pinion made so that it can be disengaged from the rack?
5. Explain the action of the feeds.
6. Why is a change in the direction of motion of the feed mechanism necessary?
7. Explain two methods for reversing the feeds.
8. Give the names of two kinds of dogs.
9. For what purpose is the dog employed?
10. Name three kinds of chucks.
11. Give a description of these three chucks.
12. Which is the best chuck for all-round work?
13. Give the names of six turning tools.
14. What chief characteristics have cutting tools?
15. Why is the tool set at right angles to the axis of the work?
16. Why should the center of a piece of work be carefully located?
17. Why should the center be drilled deeper than the angular part of the center?
18. What is meant by the expression "ride on the center"?
19. How is the approximate alignment of the center obtained?
20. How is the final alignment tested?

## EXERCISES FOR PRACTICE

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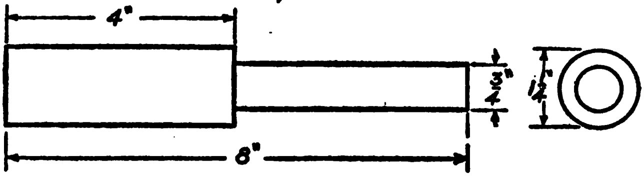


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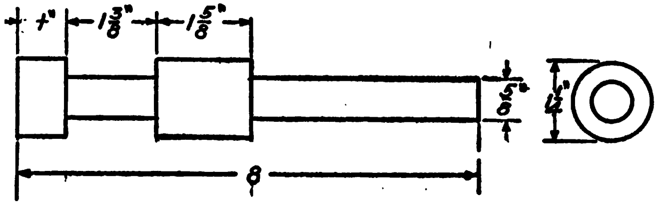


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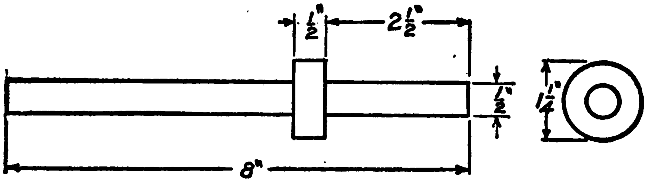


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# CHAPTER VI

## TAPER TURNING

Taper turning is making one diameter of a piece of work smaller than the other. The turned part between the two diameters must form a cone of regular increasing diameters from the small to the large end.

External and internal tapers are produced with the lathe and are often called inside and outside tapers. The tool must always be on the center when turning or boring tapers. If it is set above or below the center the resulting taper will be less than that for which the lathe was set and will also be slightly concave.

Several different methods are employed to make tapers. The better methods are by means of "the taper attachment," by setting over the tail stock, and by "seting the compound rest at an angle."

**The Taper Attachment.**—In Figure 59 is shown a top view of one style of taper attachment. W represents the ways of the lathe. On the back of the ways is secured the angle plate, P, which can be moved along the ways to any position desired. G is a guide bar which swivels at the point R and can be clamped at the end. The sliding block, S, moves freely along the guide. If the nut, which by means of the cross feed screw moves the cross slide, A, transversely over the ways, is disengaged, the cross slide with bar, B, will have free motion on its ways. When the bar, B, which is one with the cross slide, is clamped to S, S will move the cross feed out as the carriage moves along the ways toward the head stock and the tool will travel in a line at an angle to the ways, thus producing a taper.

*Inches Per Foot.*—When a taper is to be turned by using the taper attachment, the taper must be ex-

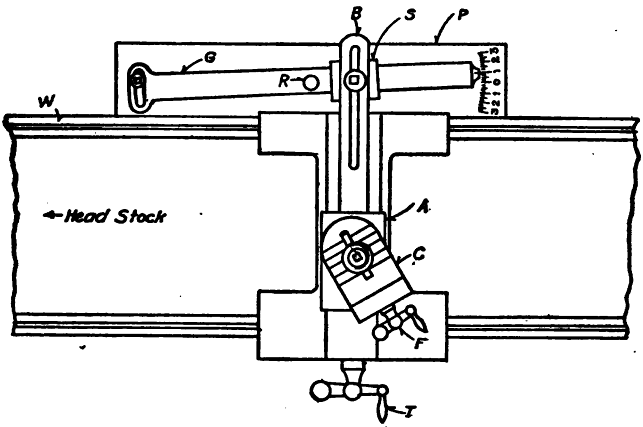



Fig. 59.—Taper Attachment.

pressed in inches per foot, because the scale for setting the taper attachment always represents inches in one foot. In the sketch, Figure 59, a scale is shown at the right and the index line on the guide is set at the mark denoting a taper of one inch in one foot.

If from the center of the guide at R to the end of the index line on the guide is just one foot or twelve inches, then the mark on the scale will have to be just ½-inch from zero on the scale. The guide must be set to one-half the taper per foot because the tool cuts on both sides of the work which is being turned. It, of course, cuts all the way around, but is spoken of as cutting on both sides for convenience of illustration.

The guide G forms an angle with the ways of the lathe and represents one side of the taper. As the piece turns around in the lathe all parts of its diameter are brought to the tool which describes this line in its travel along the ways toward the head stock. If the guide bar were set so that it had an inclination of one inch in one foot, a taper of two inches to the foot would be produced. A taper of one inch to the foot means that a diameter which is just one foot from any certain point is either one inch larger or smaller than the diameter at this point. Sometimes the taper per foot is not marked on the drawing, but diameters in inches at two points are given, also the distance between these two points. In a case of this kind the taper per foot can be found by subtracting the small from the large diameter and by dividing the remainder by the length of the tapered part; then this quotient multiplied by twelve will give the taper per foot. When a taper attachment is used as shown in Figure 59, the tool must be fed to the work, for depth of cut, by means of the compound rest, C, with its feed handle, F.

*Lost Motion.*—In taper attachments there is necessarily a number of moving parts connected, which will introduce more or less lost motion or back lash.

After a cut over the work is taken, and the tool is brought back by the carriage to the starting point for another cut, the lost motion will allow the tool to travel straight for a short distance, thus making the piece straight, not tapered as desired. The cut will not be tapered until all the back lash is taken up, when the tool will start off on the required taper. This can usually be overcome by bringing the carriage back until the tool point is a little farther back than the starting place of the cut. This will allow the lost motion to be all taken up by the time the tool reaches the place where it starts to cut.

It is not necessary to let the feed bring the tool up to the cut as it can be brought up quickly by the hand feed, because the only requirement is to carry the tool far enough back to take up the slack by the time it reaches the place where it begins to cut.

*Small Diameters.*—On small diameters the tool cannot be brought enough beyond the end of the work to take up the slack because the tool will then strike the center of the lathe. In a case of this kind, the back lash can generally be taken up by pulling out or pushing in on the tool post, depending on the direction the guide is set to turn. Thus, if it is set as shown in the sketch, it is making an increasing taper from the tail stock toward the head stock; the end nearer the head stock will be closer to the ways and the inside face of the sliding block, S, will be forcing the tool back from the center of rotation. It will then be necessary, in taking up the lost motion at the beginning of the cut, to push the tool toward the center. If the guide is set at the opposite angle, or the end nearer, the tail stock is closer to the ways; the outside face of the block will be pulling the tool, and the tool post must then be pulled out or away from the center.

*Internal Tapers.*—When producing internal tapers, the piece is either held in the chuck or clamped to the face plate while the hole is bored, the taper attachment being used in the same way as for external tapers. The taper attachment is set to the taper per foot regardless of the length of the piece to be turned. Most taper attachments are capable of making tapers up to 4 inches per foot.

**External Taper Turning by Setting Over the Tail Stock.**—As stated before, when centers are not in line and the cut is not running parallel, but taper, they can be brought into alignment by adjusting the tail stock. Therefore, by the same means, they can be thrown out of alignment and thus produce a taper. As all engine lathes are provided with a set-over adjustment in the tail stock, this method of turning tapers is always available. Because the amount of side adjustment is limited, only slight tapers can be produced by setting over the tail stock, and especially so in cases where the work is long.

*Calculating the Set Over.*—If the tail center is thrown out one inch and the piece is one foot long, the taper will be two inches in one foot; but, if the piece is two feet long, the taper will be only one inch, and, if four feet long, it will be a ½-inch taper per foot. From this it is evident that the length of a piece must be considered when calculating the set over. To illustrate, let it be supposed that a piece is just twelve inches long and is placed between the centers of the lathe, with some means of driving it so that it can be turned from one end to the other. This is shown in Figure 60. If this piece is just 12 inches long and is to be tapered ¾-inch to one foot, the large end being 2 inches, ¾ of an inch must be removed from the small end. As the tool cuts all around the piece (cuts on both sides), the center must be thrown over ⅜ of an inch, which fact will cause ¾ of an inch to be taken off at the start. The cut will run out to nothing at the other end. If the above is true, it follows that, if the piece were only half as long, the set over should be only ½ of ⅜, or 3/16; and, if it were twice as long, the set over must be twice ⅜, or ¾, to

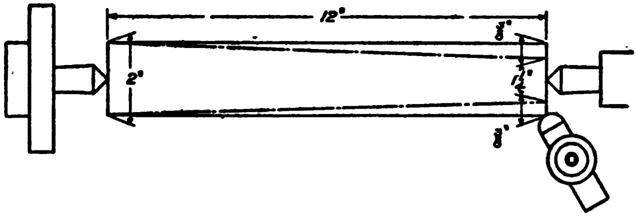



Fig. 60.—Example.

produce in either case a taper of ¾ of an inch in one foot.

*Rule.* To obtain the set over mathematically, divide the taper per foot by 12 to get the taper of one inch, and multiply this quotient by the length of the piece. Now, as said before, the lathe "cuts on both sides"; therefore, this product must be divided by 2 to obtain the proper setting.

By graphic illustration in Figure 60, it is shown that the dead center must be thrown over ⅜ of an inch so that the tool will cut on the dotted line. Mathematically this amount can be found thus:

$$\frac{\frac{1}{12}\times\frac{3}{4}\times\frac{12}{1}}{2} \text{ equals } \frac{3}{8}, \text{ equals } \textit{set over}.$$

*Example.*—In Figure 61 a case is given where the piece is not twelve inches long. The set over can be found by the same formula, thus:

$$\frac{\frac{1}{12} \times \frac{3}{4} \times \frac{23}{2}}{2} \text{ equals } \frac{23}{64}\text{, equals } \textit{set over.}$$

It must not be supposed that this formula will give the set over for all problems. This one is correct

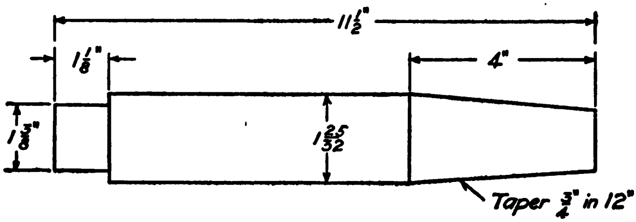



Fig. 61.—Example.

where the taper per foot and the length of the piece are given.

*Example.*—Figure 62 is a case where the diameters

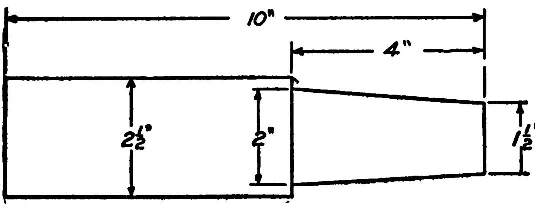



Fig. 62.—Example.

at both ends of the tapered part are given, also the length of the tapered part. To find the set over for this, subtract the small from the large diameter, divide this difference by the length of the tapered part; the quotient thus found, multiplied by the total length of the piece and then divided by 2, will give the set over for the tail stock.

$2'' - 1\frac{1}{2}'' = \frac{1}{2}''$, equals amount of taper in tapered part;

$\frac{1}{4} \times \frac{1}{2} = \frac{1}{8}$, equals taper per inch;

$10 \times \frac{1}{8} = {}^{10}/_{8}$ inches, equals $1\frac{1}{4}$-inch taper in 10 inches;

$\frac{1}{2} \times {}^{10}/_{8} = \frac{5}{8}$, equals set over for tail stock.

In the preceding calculation, the taper per foot can be found. Then, the first formula will serve to complete the calculation, thus:

$2 - 1\frac{1}{2} = \frac{1}{2}$, equals amount of taper in tapered part;

$\frac{1}{4} \times \frac{1}{2} = \frac{1}{8}$, equals taper per inch;

$12 \times \frac{1}{8} = 1\frac{1}{2}$, equals taper per foot;

now, using the first formula,

$$\frac{\frac{1}{12} \times 1\frac{1}{2} \times \frac{10}{1}}{2} \text{ equals } \frac{5}{8}$$

*Tail Stock.*—In Figure 49 an end view of the tail stock is shown. Here the sub-base has a scale and the head stock an index line. These are not, however, provided on all lathes; some are left blank for the operator to make a line on the tail stock and sub-base at the position where the lathe turns straight and to use this line with the dividers to obtain the proper setting. The scales that are provided cannot always be relied on.

*Proper Setting.*—To obtain the proper setting, set the dividers to the required amount (in the case of Figure 62 it is $\frac{5}{8}$-inch). After the dividers have been set to ⅝-inch, place one point on the line on the sub-base, then bring the tail stock over until the other point will fall into the line on the tail stock. The setting will now be completed. This setting is only approximate. The exact amount must be found by trial. The turned-piece should first be turned slightly large and then tried in the hole it is to fit or in a gauge similar to the hole. It is better to be sure that the taper is too great rather than too little. If it is too little and the small end is turned to nearly the proper size, the large end may be too small.

*Final Test.*—A good way to prove the final fit is to make three lines with chalk, lengthwise on the surface and about equal distances apart. Insert the work in the bore and turn it carefully through a complete revolution, in the opposite direction to that in which it rotated in the machine. If the chalk marks have been rubbed equally their entire length, the taper is correct. If the chalk marks have been rubbed at one end and not at the other, a further adjustment must be made and another cut taken.

*Objection.*—When the tail stock is thrown over, the axis of the work does not stand at right angles to the face plate. It is necessary to allow for some in-and-out motion for the tail of the dog through the face plate. There is one objection to making tapers by setting over the tail stock and this is that the centers do not fit the work correctly, but for ordinary purposes this method is practical.

**Taper Turning by Setting the Compound Rest at an Angle.**—Sometimes it is necessary to turn tapers that are too steep to be done either by using the taper attachment or by setting over the tail stock. Such tapers can be made with the compound rest. Its construction is such as to allow the upper slide which carries the tool to be set and secured at any angular position with the cross slide, thus enabling the turning or boring of any steep taper. Steep tapers are usually short and, although the range of feed is small, it is seldom that the tool must be reset in turning any ordinary taper.

*Finding the Setting.*—The setting for the compound rest can be found mathematically and either a protractor or the graduation on the slide can be used for gauging the angle required. In Figure 63, at a, a hole is to be bored. The taper per foot is $\frac{3-1}{4}\times 12$, equals 6 inches, equals the taper per foot. This taper is too steep for any taper attachment and must be done by the compound rest.

*Rule.*—To get the setting mathematically, find the tangent of the angle A by dividing 1 inch, the leg opposite, by 4 inches, the leg adjacent; thus, ¼ equals .25, equals the tangent of A, equals about 14°. When the tangent is found, the corresponding angle can be obtained by referring to a table of natural tangents. .250 corresponds to about 14°. Setting the compound rest by the graduations on the swiveling part to 14° will produce the taper. Of course, the rest must be swung into the proper direction, which fact will be evident from the work in hand. The feeding of the tool must be done by hand, as there is no power feed on the compound rest.

*Use of Protractor.*—Another way to set the compound rest is to use a protractor. Set the protractor to the required angle. Place the base either along the cross slide or on the face place of the lathe. Swivel the compound rest until the protractor bladė fits along the slide of the compound rest. Clamp the rest

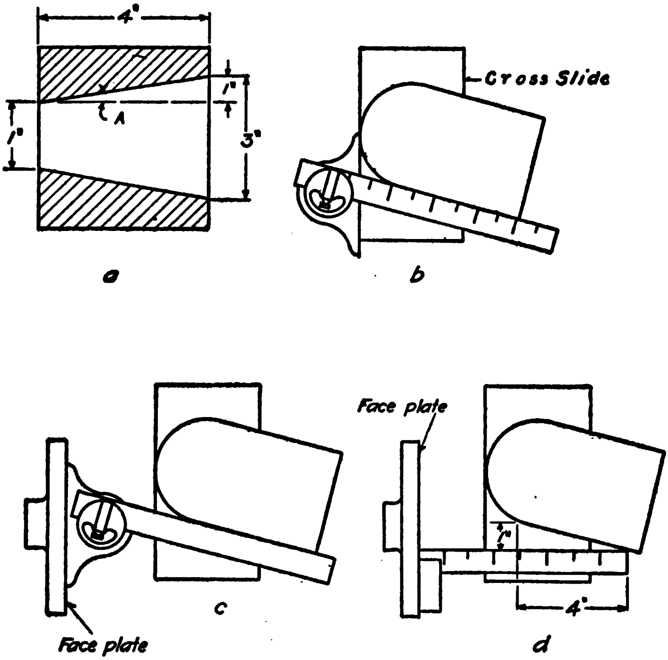



Fig. 63.—Setting of Compound Rest.

and it is ready for turning the taper. These two methods are shown at b and c, Figure 63.

*Use of Square and Rule.*—In d, Figure 63, is shown a way to set the compound rest by means of a square and rule. The angle of the taper has an increase of

1 inch in four. With the square held against the face plate, the compound rest can be swiveled until at 4 inches from the end of the square it is just 1 inch to the edge of the compound rest.

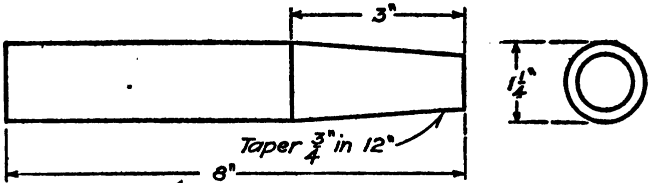
The compound rest is convenient for turning the centers of the lathe. Angular work, such as bevel gears, can also be done to good advantage.

## QUESTIONS ON CHAPTER VI

1. What is taper turning?
2. Why should the tool be placed on the center in taper turning?
3. Name three different methods of turning tapers.
4. Describe the taper attachment.
5. What is the cause of lost motion in the taper attachment?
6. What is the effect of the lost motion on the taper?
7. How can it be overcome?
8. What is meant by the expression "a taper of 1 inch to the foot"?
9. If the large diameter of a taper is 3″ and the small 2″, the distance between these two diameters being 4″, what is the taper per foot?
10. When setting the taper attachment, is it necessary to consider the length of the piece being turned?
11. Give the set over of the tail stock for turning a taper on a piece which is 8″ long, having a tapered part on it which is 4″ long; the diameter at the large end of the tapered part is 2″ and the taper is ¾″ in 12″.
12. Explain the method of setting the tail stock with the dividers.
13. How is the fit of a taper tested?
14. How is the final adjustment made?

15. What is the objection to turning tapers by off-setting the tail stock?
16. What sort of tapers are turned with the compound rest?
17. Explain the methods of setting the compound rest to the required angle.

## EXERCISES FOR PRACTICE

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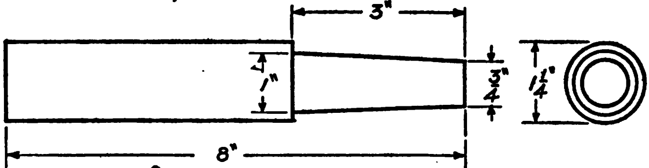


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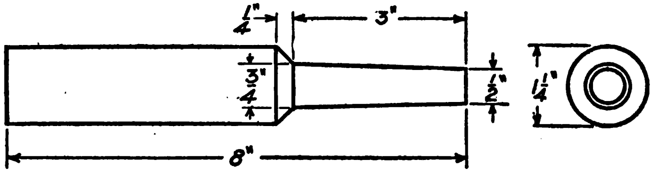


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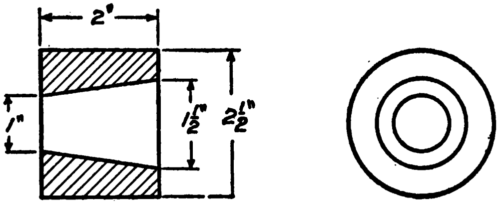


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# CHAPTER VII

## THREAD CUTTING ON THE LATHE

**Thread.**—A thread is the spiral part of a screw. If a strip of lead which has a triangular section of 60° were wound around a cylinder so that the edges of the strip were close together and so covered all of the cylinder, a true sharp V-thread would be formed. This, however, would not make a substantial screw. But, if a spiral V-groove were cut upon the cylinder, a substantial V-thread would be formed. Spiral grooves of different cross sections are made on round pieces of metal and are called threads. Threads are made both right and left hand. A right-hand thread is one which has to be turned clock-wise to insert it in a nut, and a left-hand is turned the reverse way. These threads have what is called *pitch* and *lead*.

*Pitch.*—The pitch is the distance from the center of one thread to the center of the next measured parallel to the axis of the screw. Thus, if it is 1/8 of an inch, the pitch is 1/8. It is usual to refer to the number of threads per inch rather than to the pitch. For example, if the pitch is 1/8 of an inch, there are 8 threads to every inch of the screw, and it would be spoken of as an eight pitch. But, it must be borne in mind that the length of the pitch is 1/8 of an inch and this must be used for all calculations.

*Lead.*—The lead of a screw is the amount a nut would travel in one revolution on the screw. If the nut would travel 1/8 of an inch in one revolution, the lead would be 1/8 of an inch.

*Variety of Threads.*—Threads are sometimes made multiple; that is, two or more threads are parallel on the cylinder. When formed by a single spiral they are called single threads; when by two, double; by three, triple; and by four, quadruple, etc. In the case of a single thread, the pitch and the lead have the same length or dimension. In a double thread the lead is twice the pitch. In a triple, the lead is three times the pitch; and in a quadruple, the lead is four times the pitch, and so on for any number of multiple threads.

**Kinds of Threads.**—There are several kinds of threads, each one having a different shape:

1st, Sharp V-thread
2nd, U. S. Standard
3rd, Acme
4th, Square
5th, Buttress
6th, Whitworth

In Figure 64, a sketch of these six threads is shown with the angles of each one marked. The dimensions of the different parts of these threads are found by formulas which have been worked out for the purpose. The parts are marked by letters which stand for the following names of the parts:

| | | |
|---|---|---|
| P = pitch | R = radius | B = base |
| D = depth | T = thickness | W = width |
| F = flat | S = space | |

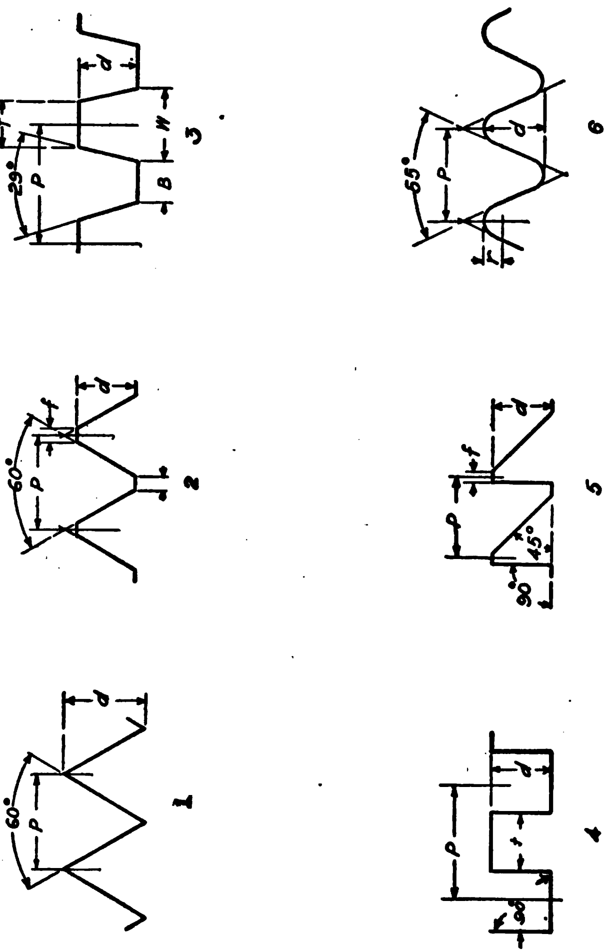



Fig. 64.—Threads.

**Formulas.**

| | |
|---|---|
| No. 1 Formula, Sharp V-thread. | $P = \frac{1}{\text{No. threads per inch}}$<br>$D = P \times .866$ |
| No. 2 Formula, U. S. Standard. | $P = \frac{1}{\text{No. threads per inch}}$<br>$D = P \times .6495$<br>$F = \frac{P}{8}$ |
| No. 3 Formula, Acme. | $P = \frac{1}{\text{No. threads per inch}}$<br>$D = .5 \times P + .01$<br>$F = .3707 \times P$<br>$W = .3707 \times P - .0052$<br>$S = .6293 \times P$<br>$B = .6293 \times P + .0052$ |
| No. 4 Formula, Square. | $P = \frac{1}{\text{No. threads per inch}}$<br>$D = .5 \times P$<br>$T = .5 \times P$ |
| No. 5 Formula, Buttress. | Varies to suit condition. |
| No. 6 Formula, Whitworth. | $P = \frac{1}{\text{No. threads per inch}}$<br>$D = P \times .6403$<br>$R = P \times .1373$ |

The amount of flat top and bottom in No. 5 determines the depth. This amount varies to suit the purpose for which the screw is made.

The depth of the sharp V-thread is the perpendicular distance from the root to the top of the thread. If the triangle of 60° is bisected by this distance, the depth which is the length of this line can be found by trigonometry, where the side adjacent = hypotenuse × cosine. Cosine of 30° = .866.

It is not necessary, however, to know why these formulas will give these dimensions. A knowledge of how to use them will be sufficient.

*Formula No. 1.*—The depth of a sharp V-thread of 10 pitch is required. According to the formula, P × .866 = depth; then .1 × .866 = .0866 = depth. Again a screw has 14 threads to the inch. The depth can be found thus: 1/14 × .866 = .061.

The angle of the U. S. standard is also 60°, but owing to its flat top and bottom the constant is not the same. The amount of flat is one-eighth the pitch. Now, if 1/8 is taken off the top and 1/8 off the bottom of a sharp V-thread, there will be left only 3/4 of the original depth; therefore, 3/4 of .866 is the proper constant, or .6495.

Apply the formula to a screw of 8 pitch, U. S. Standard, thus: 1/8 × .6495 = .0811, or .125 × .6495 = .0811.

The other formulas can be used in the same way; it is merely a matter of multiplication or division, as the case may require. When cutting threads on the lathe, it is not always necessary to know the depth because the thread is cut down until it fits a gauge and the depth will then be correct. But, where a piece is to be bored out to the proper diameter, allowing enough to form a correct thread, the depth must be obtained and the hole bored to a diameter which is twice the depth of the thread less than the outside diameters of the screw which is to fit in the threaded hole.

**Thread Cutting.**—A thread is cut on the lathe by clamping in the tool post a tool with the proper shape of the desired thread and causing it to move along the ways at a rate which will produce the pitch of the screw wanted. Every revolution of the piece in the lathe must make one pitch. Therefore, the tool must move along the ways the distance of one pitch for each revolution. To obtain this movement, change gears are employed which will give the proper ratio between the spindle of the lathe and the lead screw.

**Change Gears.**—Change gears are wheels with teeth cut on their circumferences. Several of these are furnished with a lathe and have different numbers of teeth. The smallest one generally has 20 teeth and the largest 120 teeth. They run in numbers according to their pitch, sometimes increasing by 4, like 20, 24, 28, 32, teeth and so on. For a pitch of 10 they would increase by 5 and for other pitches by a number which is a divisor of the pitch. Any of these gears can be placed on either the stud or the lead screw to obtain different ratios.

When cutting threads in the lathe, the carriage carrying the tool is moved along the ways by means of the lead screw which has a certain number of threads per inch on it. Let it be supposed that the lead screw has eight threads per inch on it and that the piece to be threaded requires eight threads per inch. It is evident that the screw must make one complete revolution to carry the tool along 1/8 of an inch and the piece in the lathe must also make one revolution at the same time to make a complete thread with a pitch of 1/8 inch. Therefore, the ratio between the spindle of the lathe and the lead screw must be one to one. The gears on the stud and the lead screw must have the same number of teeth for a ratio of one to one.

*Ratio of Gears.*—Change gears must of necessity be of different diameters to obtain distinct ratios, thus making the distance between the teeth of one set of gears more or less than that between the teeth of the other set. The idler must be employed to give motion from the stud gear to the one on the lead screw and to make up the difference between the teeth of the two gears. In simple gearing the idler does not change the ratio and can have any convenient diameter or have any number of teeth.

Suppose a case where the lead screw has 8 threads per inch, or the pitch is 8, and a pitch of 16 is to be cut. This pitch of 16 is finer than that of 8, therefore the lead screw must not make a whole revolution each time the spindle of the lathe does, but the ratio should be 8 to 16 or 1/2. The gear on the stud must have (say) 30 teeth and the lead screw 60 teeth.

*Rule for Gears.*—To find the proper gears to cut any thread with any lead screw mathematically, put down the number of threads per inch on the lead screw and mark it screw. Below this number place the number of threads per inch that are to be cut. Mark it, for convenience, stud. These numbers represent the ratio and, if it were possible to have gears with 8 and 16 teeth, these would cut the screw required. Now, as 8 and 16 are impossible gears, multiply them both by some number to obtain gears with a suitable number of teeth, thus:

$$\begin{array}{ll} \text{screw} & 8 \times 4 = 32 \\ \text{stud} & 16 \times 4 = 64 \end{array}$$

Gears with 32 and 64 teeth will cut 16 threads per inch where the lead screw has 8 threads. It is evident that the screw must make fewer revolutions than does the spindle; therefore, 32 must go on the stud and 64 on the screw, provided the ratio between spindle and stud is one. In some lathes the ratio between the spindle and the stud is other than one. When calculating for change gears this difference in ratios must be taken into consideration. For example, the ratio between spindle and stud is two to one; for a case like this the stud gear must have twice the number of teeth which would be required were the ratio one to one.

*Simple Device.*—A simple way to save reasoning which gear goes on stud and which on screw is to draw a line diagonally from the number marked stud to the upper number in the final ratio and, likewise, a line from the number marked screw to the lower number of this ratio. Now, following back these lines from these numbers shows that 32 goes on stud and 64 on screw, thus:

$$\begin{array}{ll} \text{Screw} & 8 \times 4 = 32 \\ \text{Stud} & 16 \times 4 = 64 \end{array}$$

*Fractional Threads.*—Half, or fractional, threads are sometimes required, such as $11\frac{1}{2}$. Two-inch gas pipe has $11\frac{1}{2}$ threads per inch. The proper gears can be found in the same way. In this case reduce 11½ to halves and the lead screw to halves, thus:

$$\frac{11\frac{1}{2}}{8} = \frac{23/2}{16/2} = \frac{23}{16} \qquad \begin{array}{ll} \text{Stud} & 23 \times 2 = 46 \\ \text{Screw} & 16 \times 2 = 32 \end{array}$$

32 goes on the stud and 46 on the screw.

**Compound Gearing.**—Compound gearing is where two or more pairs of gears are used (the pairs being offset from each other) to make up the train to give the proper ratio. They are generally arranged as shown in Figure 65. The first and the second idlers are keyed on a sleeve and revolve together. The lead screw gear must be offset to mesh in the second idler.

*Necessity.*—To illustrate the necessity of compound gearing, let it be supposed that 80 threads per inch are to be cut with a lead screw having 8 threads. Figure this for simple gearing thus:

$$\begin{array}{ll} \text{Screw} & 8 \times 4 = 32 \\ \text{Stud} & 80 \times 4 = 320 \end{array}$$

A gear with 320 teeth must of necessity be over two feet in diameter and would probably be so large that it would not mesh with the stud gear as the centers of these two gears would be about 15 inches. Only in very large lathes are the centers of the stud and the lead screw 15 inches apart and thus allow these two gears to mesh. Compound gearing remedies this and makes it possible to use smaller gears.

*Rule.*—To get the proper gears for compounding a train to cut 80 threads with a lead screw of 8 threads, put down the ratio as for simple gearing 8/80; now factor both terms of this ratio, thus:

$$\frac{8}{80} = \frac{2 \times 4}{8 \times 10}$$

Multiply each term by the same number (say 12)—

$$\frac{24}{96} \times \frac{48}{120}$$

These gears 24, 96, 48, and 120 must be put on in the order as shown by the line; namely, 24 on the stud, 96 on the first idler, 48 on the second idler, and 120 on the screw. The arrangement of these gears is shown in Figure 65. Both terms of either ratio must be multiplied by the same number, but either ratio can be multiplied by a different number.

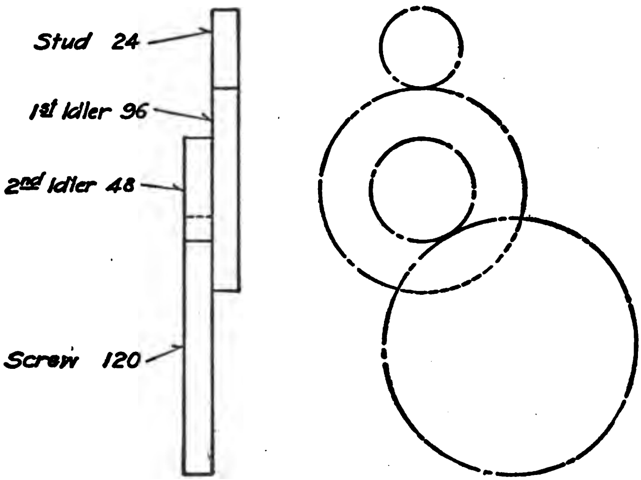



Fig. 65.—Arrangement of Compound Gears.

Modern lathes have a table secured to some convenient part of the machine showing what change gears to use for cutting different threads. It is well, however, to be able to compute these tables.

**Setting the Tool.**—The next steps after learning

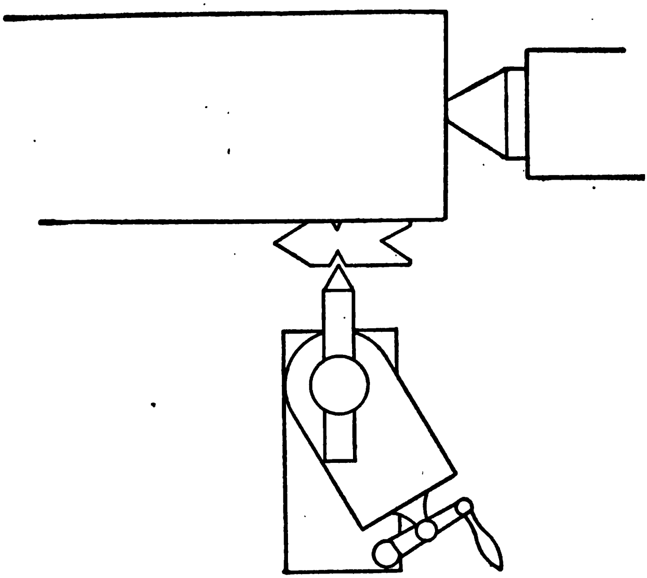


Fig. 66.—Tool Setting.

how to gear the lathe are the setting of the tool and the operating of the carriage. The threading tool is firmly clamped in the tool post with its center line at right angles to the axis of the work. This can be done by means of the center gauge, as shown in Figure 66. The height of the tool should be such that its top face lies in a radial line drawn from the center of the work. If set above or below this position the angle of the thread cut will not be the same angle as that of the tool.

Setting the compound rest at an angle of 30° or 40° will facilitate the resetting of the tool should it need grinding before the thread is finished. When the compound rest is set at an angle the tool can be clamped in the tool post, after it is reground, and be set with the center gauge as before. It then can be brought into the proper path by moving it to one side or the other with the compound rest slide while not altering the angular setting.

**Operating the Carriage.**—If the thread is to be right hand the carriage must travel toward the head stock when the spindle of the lathe is revolving in the forward direction. If left hand, the carriage must move in the opposite direction when the spindle is running forward and the cut must be started near the head stock and run toward the tail stock. Reversing the direction of rotation of the lead screw will cause the carriage to move in the opposite direction while the spindle is running forward. The reversing of the lead screw has been explained in Chapter V and illustrated in Figure 52.

After the tool is set the carriage must be engaged to the lead screw by means of the split nut.

*Returning the Tool to the Starting Point.*—It is not practical to cut a thread with one cut. Therefore, several cuts must be taken, one after the other. When the tool has reached the end of the first cut, it must be withdrawn before returning the tool to the point of starting for another cut. Returning the tool to the starting point can be done in different ways, either by reversing the rotation of the lathe spindle, which will reverse all moving parts of the lathe, or by reversing the rotation of the lead screw; or by disengaging the lead screw by means of the split nut and running the carriage back by hand. Another method is by means of what is called an indicator which indicates the point where the nut can be dropped in after the carriage has been run back by hand. In every case the tool should be carried slightly beyond the starting point in order that the lost motion will be taken up by the time it enters the cut.

In the first method, that of reversing the lathe spindle, the lost motion will hinder the tool from traveling back through the same path, causing the tool to mar the thread, or the work running backward might break off the point of the tool if it is not withdrawn when returning to the starting point. The subsequent methods for this and other reasons require the tool to be withdrawn.

*Successive Cuts.*—Each succeeding cut must be slightly deeper than the previous one. The amount of this depth must be gauged by means of a graduated dial on the lathe cross feed screw, or a threaded stop screw which can be turned back slightly for each cut, thus allowing the tool to be fed in a small amount each time.

As the ordinary threading tool cannot be given any top rake, it does not cut free. Great strain is consequently put upon it and it is a hard tool to keep in shape and in proper condition. When the lathe is provided with a compound rest the tool shown at a, Figure 67, can be used for cutting threads. At b,

Figure 67, the compound rest is shown set to an angle of 60° with the center of the work.

*Example.*—If the tool shown in Figure 67 is used, which is ground to an angle of 60° and can be set with

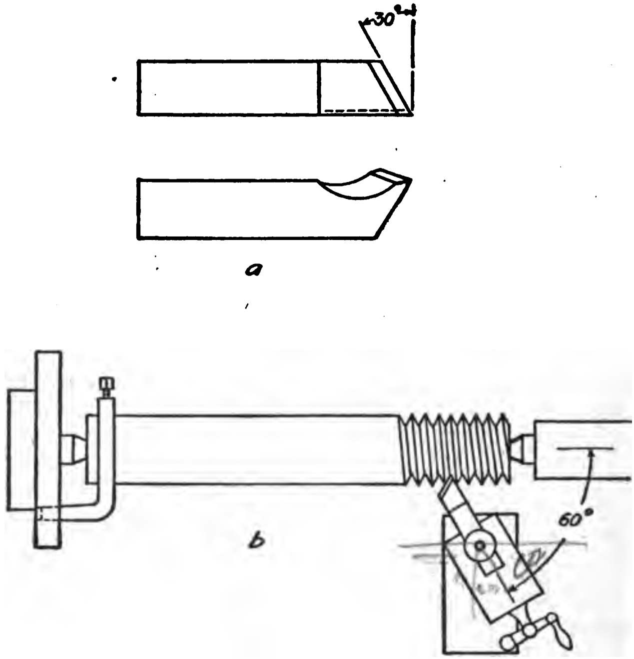



Fig. 67.—Threading Example.

the thread gauge in the usual way, a V-thread can be cut which will be quite smooth. This tool is given top rake on one side and will cut a clean chip. The feeding for the depth of each cut must be done by the compound rest slide. Each cut being necessarily a small amount, the right-hand side of the groove will be smooth and an angle of 30° will be generated by the compound feed. The left-hand side of the groove will be smooth owing to the rake of the lip of the tool. The angle will be correct because the lip was set at 60° with the axis of the work.

**Double Threads.**—When cutting double threads it is necessary after the first thread has been cut to advance the cutting tool one pitch or one-half the lead. This can be done in different ways. In lathes where the ratio between the spindle and stud is one, mark a tooth on the stud gear and a corresponding space on the idler; then mark the tooth that is exactly opposite the first marked tooth on the stud gear. Now drop the idler out of mesh with the stud gear and revolve the spindle of the lathe until the second marked tooth on the stud gear will drop into the marked space on the idler. Raise and clamp the idler and the lathe is now, what is called, *indexed* for the second thread, which can be completed in the same manner as the first.

*Ratio.*—If the ratio between the spindle and stud is other than one, the stud gear must be rotated at a rate proportional to that ratio. For example, if the ratio of the spindle to the stud is 2 to 1, that is, the spindle makes two revolutions to one of the stud, then the stud gear must be marked at a tooth which is just one-quarter of the circumference from the first marked tooth and the spindle must be rotated until *this* tooth will drop into the marked space in the idler.

A better way to cut the second thread is to have a face plate with equally divided slots and to place the tail of the dog in a diametrically opposite slot from the one with which the first thread was cut.

**Sufficient Clearance.**—Another important thing to be observed in thread cutting is that the cutting tool has sufficient clearance, especially on the lead side; on the other side the angle of the thread naturally gives the tool clearance. If the clearance is insufficient the tool will rub on the heel and is likely to dig in and spoil the thread.

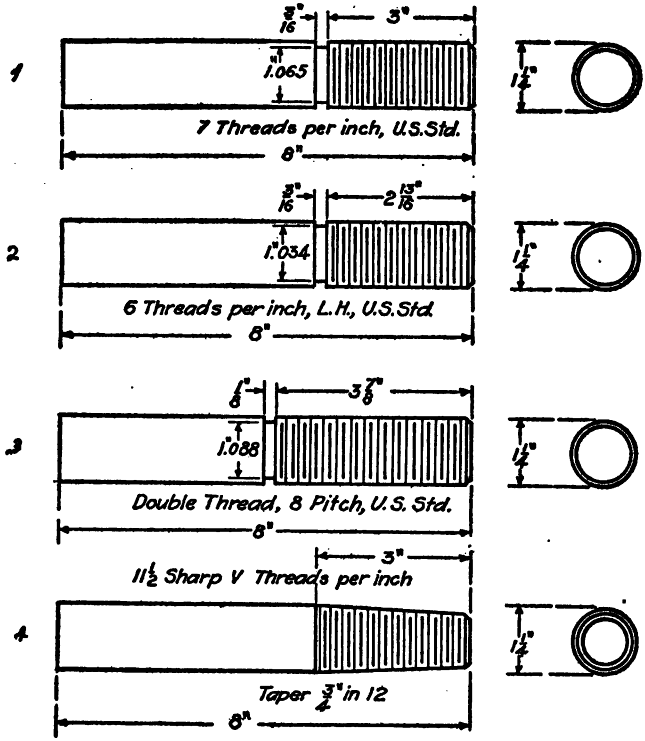
When the piece is removed from the lathe for the purpose of testing the thread with a gauge or in the place where it is to fit, care must be taken that it is put back again with the tail of the dog in the same slot as before, provided further cutting is to be done to make it fit the gauge.

## QUESTIONS ON CHAPTER VII

1. Give a definition of a thread.
2. How are threads formed?
3. What is the pitch of a thread?
4. What is the lead of a thread?
5. What are right hand and left hand threads?
6. What is the relation between the pitch and the lead of a single, double, triple, and quadruple thread?
7. Name six different kinds of threads.
8. What is the depth of a sharp V-thread of seven pitch?
9. What is the length of the flat on a U. S. Standard thread of 8 pitch?
10. What is the depth of a U. S. Standard thread of 4 pitch?
11. A hole is to be bored and threaded to fit a screw which is 2″ in diameter, with 8 threads per inch U. S. Standard on it. To what diameter should this hole be bored before cutting the thread?

12. How is a thread made in the lathe?
13. How are ratios between the spindle and the lead screw obtained?
14. What parts of the lathe cause the carriage to move at the proper rate when cutting threads?
15. In simple gearing, does the idler affect the ratio?
16. A lathe is provided with change gears having the following number of teeth: 20, 24, 28, 32, 36, 40, 40, 44, 46, 48, 56, 72, 84, 88, 96, 120. The spindle and stud ratio is one to one. The lead screw has eight threads per inch. What two change gears should be used to cut each of the following numbers of threads: 8, 9, 11½, 14, and 22? State which gear goes on the stud and which on the screw.
17. Give the compound gearing for the above lathe to cut 56, 60, and 80 threads.
18. How should the height of the tool be set when cutting threads?
19. Why is it a good plan to set the compound rest at an angle when cutting threads?
20. In what direction should the spindle of the lathe rotate when cutting a left hand thread?
21. Why is it necessary to take several cuts when cutting a thread in the lathe?
22. Why must the tool be withdrawn from the cut when returning it to the starting point?
23. How is the lathe indexed when cutting double threads?

## EXERCISES FOR PRACTICE



# CHAPTER VIII

## LATHE WORK

The general cutting tools used on the lathe and the dog have been explained in Chapter V.

**Drill Holder.**—The drill holder and mandrel, two tools used almost exclusively on the lathe, are shown in Figures 68 and 69. When a taper shank drill is used in the lathe a holder such as shown in Figure 68 is excellently adapted. The drill is inserted in the holder as shown. With the center in the holder placed on the tail center and the handle resting on the carriage, the drill can be fed to the work by means of the tail stock spindle.

**Mandrel.**—An almost indispensable tool for the lathe is the mandrel, shown in Figure 69. A mandrel is a tool upon which work that is to be machined between centers is held. There are several varieties of mandrels. The most generally used, however, are the solid and the expanding type.

*Solid Mandrel.*—The solid is made with a taper of about 1/2/1000 per inch of length in order that it may be forced to a tight fit in the bore of the work. The small end of the mandrel is a little under the normal size and can be designated by noting the fact that the size of the mandrel is always marked on the large end, consequently the unmarked end is the smaller one. Both ends are turned a little smaller than the body, and

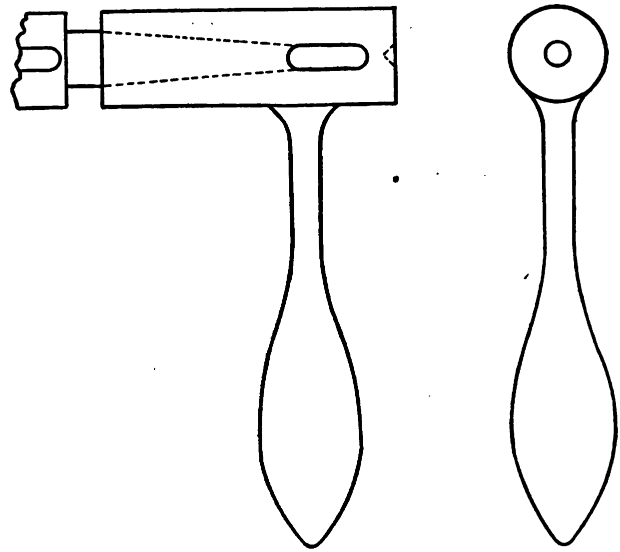


Fig. 68.—Drill Holder.

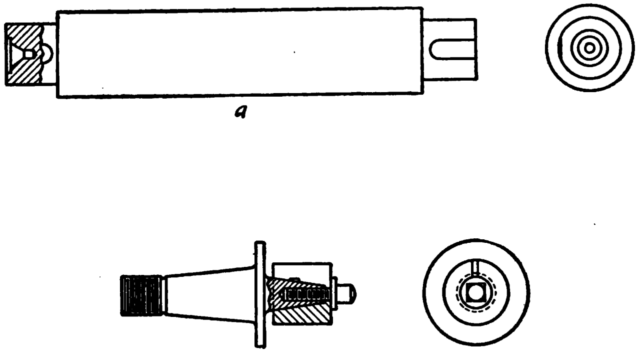



Fig. 69.—Mandrels.

a flat place is milled on them for the set screw of the dog.

*Accuracy.*—The accuracy of a mandrel depends chiefly upon its centers; therefore, great care should be exercised in forming them. A section of the center is shown in the sketch. The ends are recessed around the center to protect it when driving the mandrel in or out of the bore of the work.

Mandrels should be made of a good grade of tool steel. After they are roughed to nearly the finished size they should be hardened and the centers lapped true. The outside diameter should be ground cylindrically true upon its centers, the mandrel being rotated on dead centers for this last operation.

*Expanding Mandrel.*—A simple form of expanding mandrel is shown in b, Figure 69. The body of the mandrel fits into the spindle of the lathe and is held in by means of a quill which passes through the spindle. Split bushings of different sizes are furnished. The bushing can be expanded by means of the tapered part of the body and the bushing, when the screw at the end is tightened.

**General Utility of the Lathe.**—Sometimes a job can be done on a lathe which could be done better on a machine designed for it, but the particular machine required may not be in the shop and the lathe is often used to do the job.

*Facing Job.*—A square plate 8 inches square and 1 inch thick requires facing on both sides. The shaper or planer would be the better machine to do this work, but it *can* be done on the lathe. Grip the piece in an independent four-jawed chuck. The jaws catch hold of the piece as shown in Figure 70, each jaw catching one of the four ends. The tool is started at the center and fed out across the piece, thus producing a flat surface. After one side is faced, the piece can be turned around in the chuck and the other side faced in the same manner. To insure that both sides of the piece will be parallel, in setting for the second side the finished side must be adjusted until its four corners are the same distance from the face of the chuck.

*Keyway for Pulley.*—A pulley requires a keyway.

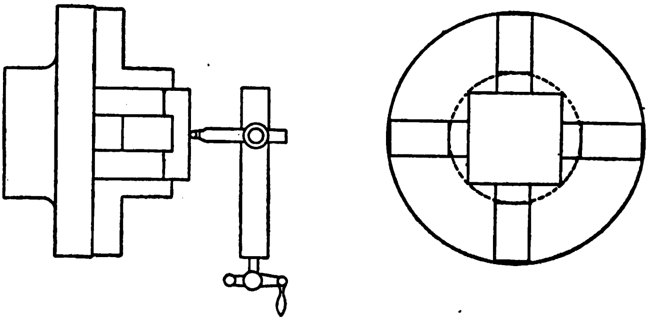


Fig. 70.—Example.

This should be done on a keyseating machine, but here again the lathe can be employed. As shown in Figure 71 the pulley has been bored and is held in the chuck. With a tool of the proper shape clamped in the tool post and moved along by means of the longitudinal hand feed through the bore, the lathe spindle not revolving, a key-way can be cut perfectly true with the bore. The tool will have to be fed for depth of cut each time before it is run through the hole. This will be a slow operation, but quicker and better than chipping and filing it.

A keyway can be cut in a shaft held between the centers in much the same way.

**Machining Various Surfaces.**—Plane, cylindrical, and tapered surfaces are readily machined with the regular tools and feeds on the engine lathe. Where spherical or irregular surfaces are to be made, a spe-

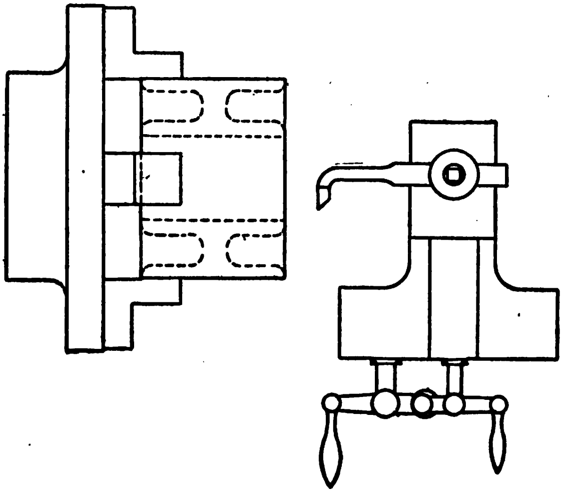


Fig. 71.—Example.

cial attachment or a forming tool must be used to produce the required shape.

*Forming Tool.*—The forming tool can be used where the work is of circular section, such as a cap for a screw jack, as shown in Figure 72. Here the stock, S, is held in a collet or chuck. The tool, T, is held in the tool post and fed to the work by the cross feed. The hole, H, is bored with a drill held in the tail stock.

After the piece is formed and drilled it can be cut off and the stock pulled out the required distance to form another piece, going through the same operation as before. The size of a piece like this that can be made with a forming tool depends upon the rigidity of the lathe; and the length of the cutting edge, upon the stiffness of the work in hand.

*Turning a Ball on End of a Rod.*—A ball can be

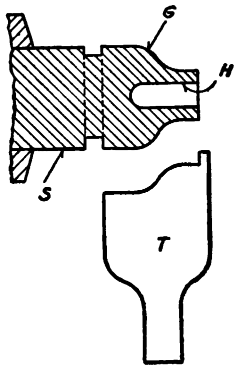



Fig. 72.—Forming Tool.

turned on the end of a rod by using the compound rest. First grip the stock in the chuck or collet, as shown in Figure 73. Here the cross feed is run in until the center on which the compound rest swivels is directly under the center line of the lathe spindle. The accuracy of the setting can be tested by taking a rough cut off the ball at approximately the center. This will produce a rough sphere. With the compound rest feed, bring the tool up until it just touches at the point marked a in Figure 73, then swing the tool around to the point marked b and, if it touches this point the same as at point a, the setting of the center is correct in the direction across the ways. If after the tool is swung to point b there is an open space between the tool and the sphere, it shows that the cross feed must be brought back enough to reduce this space one-half its amount. When the tool in swinging around touches both points the same, the center of the compound rest is properly located in one direction. To center in the other direction the carriage must be

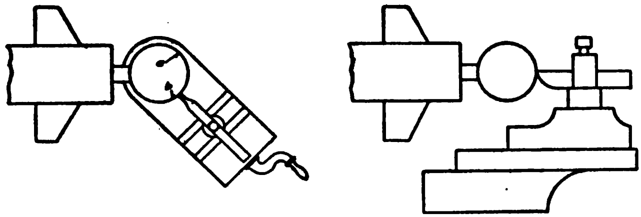


Fig. 73.—Ball Turning.

moved along the ways until the center is in the proper place.

The feed for depth of cut and to make the ball the proper size is secured by means of the compound rest slide and its feed handle. The cutting feed is obtained by pulling the compound rest around by hand, the clamping screws being left loose enough to allow the rest to rotate.

*Special Forming Attachment.*—When the outline is irregular and too long to be produced with a forming tool, the taper attachment principle may be applied. This is done by having a guide of the same outline as the piece to be turned clamped to the taper attachment. The cross feed is free to slide in and out. A point is fastened to it in line with the point of the cutting tool. A spring is attached to the cross feed which pushes it in, thus keeping the point always against the guide, causing the tool to follow its outlines. This is shown in Figure 74.

With this arrangement, the point which is fastened

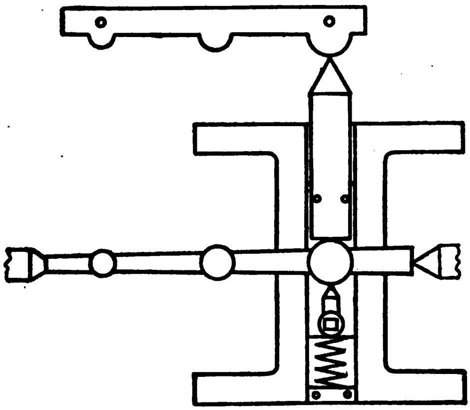


Fig. 74—Forming Attachment.

to the cross feed will not ride up on the curves of the sphere on the guide and a cut cannot be taken in the usual way but must be started at the top for either side of the ball; the point will then follow down the guide and produce the proper shape.

*Wristpin of Crankshaft.*—The wristpin of the crankshaft in Figure 75 is to be turned. The shaft proper should be roughed down to nearly size. Two cast-iron discs or cranks must be furnished whose diameters are a little larger than twice the throw of the crank. These discs must be bored to fit snugly the ends of the shaft and a center must be formed in the face of each one equal to the throw of the crank. To locate the offset centers of these discs on the shaft, place it on a surface table resting the turned part in V-blocks. The V-blocks must be high enough to let the discs swing free of the surface table. With a

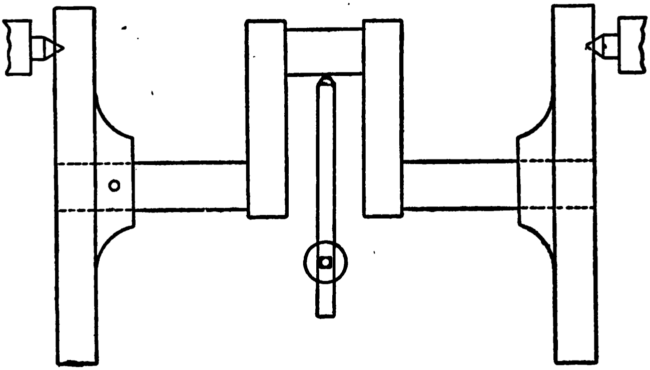


Fig. 75—Turning of Wristpin.

surface gauge set the approximate center of the wrist-pin, the centers of the shaft, and the offset centers in the discs, all in the same plane. Clamp the discs in this position by means of the set screws in their hubs. The job is ready to turn the wristpin in the lathe. By placing the shaft on the offset centers the center of the wristpin will be in the center of rotation and by employing a long tool that will reach it through the crank arms of the shaft the turning can be done. A counterweight should be placed on the face plate opposite the shaft to give a smooth rotation to the lathe. Considerable care must be exercised in turning this pin, as the shaft is easily sprung. A block of wood or a rod of iron, fitted between the disc at the offset center and the wristpin on either side of the crank, will materially help to prevent its springing.

**Boring.**—A large percentage of the work done on a lathe is boring; an example of boring and turning on a mandrel is shown in Figure 76. A gear blank is to be bored and turned from a casting, the hole is to be 1½ inches in diameter, the outside diameter is 6 inches, and the thickness of the blank 1¼ inches. Enough stock has been left to true the wheel up all over. The hole is to be drilled and bored.

*Adjustment.*—The first operation is to grip the casting in the chuck and adjust it until it runs true; then with a centering tool form a countersink for starting the drill. This is shown at a in Figure 76.

*Drilling the Hole.*—The next operation is to drill the hole with about a 1¼-inch drill, which is shown at b. The drill is held in a drill holder, the arm of the holder resting on the carriage of the lathe. The center of the holder fits into the tail center and is fed by the tail spindle screw. The countersink, even if it is true, will not insure that the drill starts perfectly true. The back of a tool held in the tool post and pushed against the end of the drill when starting will make it run true. When the drill has entered to nearly its diameter, this tool can be withdrawn and the drill be left to take its proper place in the center of the hole which is being drilled. The tool at the end of the drill is shown at b, Figure 76.

*Drawing In.*—When the drill is breaking through

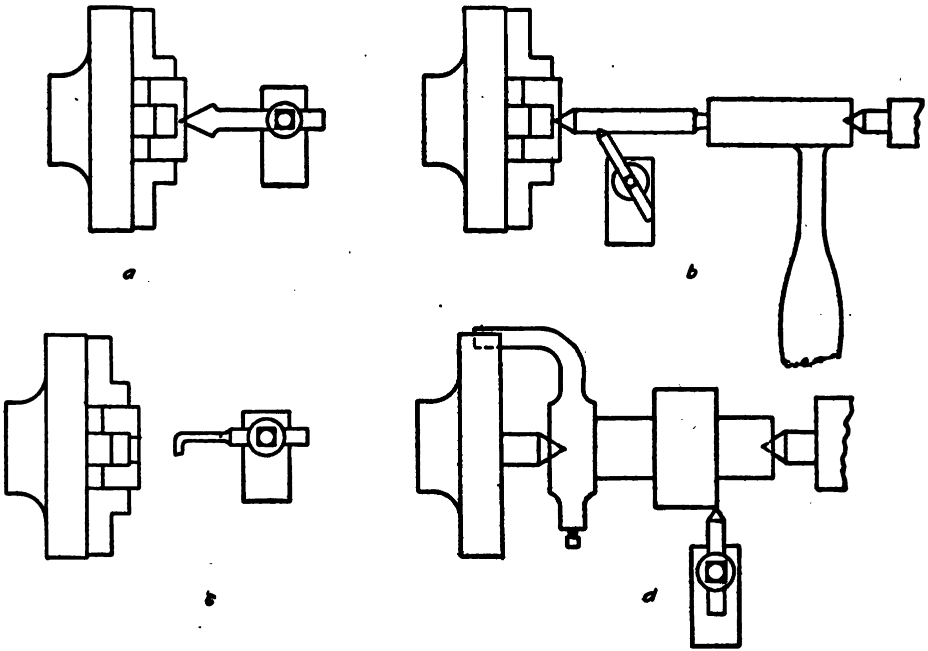



Fig. 76.—Boring and Turning on a Mandrel.

the end of the hole, there is a tendency for it to draw in and pull the holder out of the tail center. If it should do this, the drill may be broken or bent. To prevent the drill's drawing in, place the arm of the drill holder against the tool post or the compound rest and feed the carriage with the drill; its weight will prevent the drill from drawing in.

*Boring to Size.*—The piece is now drilled and ready to be bored to size by a boring tool, as shown at c. The boring tool should be as stiff and rigid as possible. As a boring tool springs considerably, the end of the hole will be somewhat larger than the balance of it because the tool does not take its full spring until the cutting edge is past the end of the bore. This can be remedied by taking light cuts when finishing. In boring parallel holes it is immaterial whether the point of the tool is above or below the center, but for tapered holes it must be exactly at the center.

*Reaming.*—The proper amount to leave for the reamer is about 1/100 of an inch, positively not more than 1/64 for a hole of this size. The reamer can be run through the hole in the same way as the drill was. The face of the casting can be machined at this time, before removing it from the chuck.

*Turning to Size.*—The last operation is to force the piece on a mandrel and turn it to size between the centers of the lathe, as shown at d. The faced side of the casting should be next the dog. The other side can be faced at the same time when the turning is done.

**Cutting Speed.**—Cutting speed is a term used to denote the speed in feet per minute, at which the outside diameter of the piece being turned is running; or the number of feet per minute the work passes the tool. The speed can be found by multiplying the diameter in feet by 3.1416 and this product by the number of revolutions per minute the work is going.

*Calculating Speed.*—A piece of work is 4 inches outside diameter and the lathe is running 40 revolutions per minute; what is the cutting speed? Four inches is one-third of a foot:

$$1/3 \times 3.1416 \times 40 = 41.88 \text{ feet.}$$

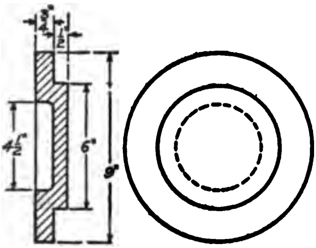
*Speed Limits.*—It is customary to run the lathe as fast as the tool will stand. For an approximate guide, the proper cutting speed, using a high carbon steel tool, is 20 to 40 feet for steel, 40 to 60 feet for cast iron, and 60 to 100 feet for brass. These are not absolute, and depend upon the stiffness of the machine and the hardness of the material being cut. The effect, both upon the output of the machine and upon the workman, makes it important that the highest speed possible, consistent with the conditions, be used. The workman likes to see the machine doing all it can.

**Cutting Feed.**—Cutting feed is a term given to the extent at which the tool is fed to the work for every revolution of the lathe and for every stroke of the planer or shaper. It is expressed in fractions of an inch as a feed of 40 means the tool is advanced to the work 1/40 of an inch for every revolution or stroke. It is governed by the stiffness of the machine and work and by the depth of the cut.

## QUESTIONS ON CHAPTER VIII

1. How is a drill held when drilling in the lathe?
2. What is a mandrel?
3. Explain how a mandrel is made.
4. Give some examples of work that can be done on a lathe that should be done on another machine.
5. Name two kinds of mandrels.
6. On what kind of work can a forming tool be used?
7. What is the important characteristic of a lathe upon which forming work should be done?
8. Explain how to form a ball with the compound rest.
9. When the outline is irregular and too long to be done with a forming tool, how is it accomplished?
10. Explain the method of turning a wrist pin on the lathe.
11. Explain the method of boring a casting 6" in diameter and 4" long, the hole to be 2" in diameter.
12. How is the drill prevented from drawing in when breaking through a hole?
13. What is the effect of the springing of a boring tool before it has fully entered the hole?
14. Is it important that the tool be on the center when boring straight holes?
15. How much should be left for the reamer in boring a 1½" hole?
16. How is the cutting speed found on a lathe?
17. What are the approximate cutting speeds of steel, cast iron, and brass?
18. What is cutting speed?
19. What is cutting feed?

## EXERCISES FOR PRACTICE

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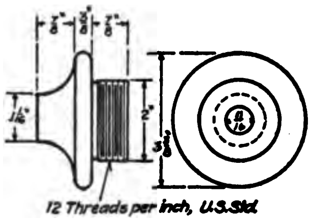


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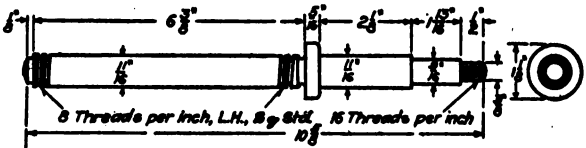


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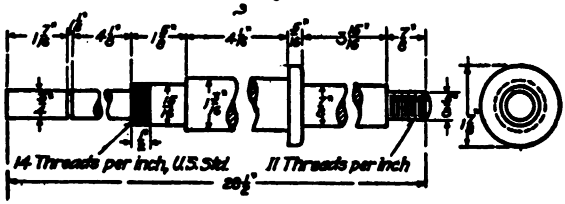


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# CHAPTER IX

## PLANER AND SHAPER

### Planer

**Planer and Shaper.**—The planer and the shaper are machines for producing plane and irregular surfaces that can be made with a straight line cut. The slotter and keyseater are modifications of the planer and shaper.

Considerable work that was formerly classed as work for the planer and the shaper is now being done on the milling machine, but there is still a wide range of work that must be done on the former machines. The cutting tools used on the planer and the shaper are practically the same as those used on the lathe, with this difference: a right-hand roughing tool for a lathe is left hand for a planer and left-hand tools are right hand. The planer and the shaper operate on flat work in much the same way as the lathe does on round.

*Difference.*—In the planer, the work when being cut moves under the tool while in the shaper the tool moves over the work. In the planer the tool is fed to the work for the successive cuts, while in the shaper the work generally feeds to the tool; but when feeding vertically the feed is given to the tool.

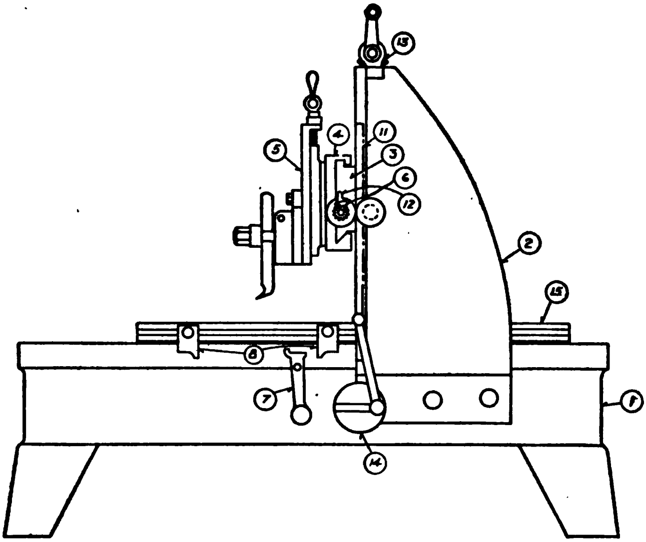


Fig. 77.—Side View of the Planer.

**Parts of Planer.**—In Figures 77 and 78 are shown a side view and an end view of a planer. The principal parts are numbered and a list of them with names is given below:

1. Bed.
2. Housings.
3. Cross rail.
4. Saddle.
5. Head.
6. Feed screw.
7. Reverse lever.
8. Dogs.
9. Rack for platen.
10. Apron or flapper.
11. Feed rack.
12. Pawl.
13. Gears for raising and lowering cross rail.
14. Feed disc.
15. Platen.

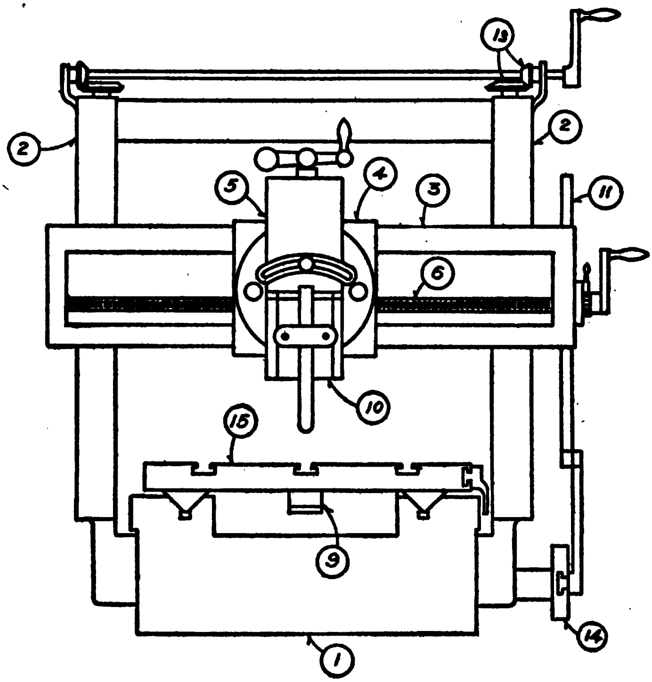



Fig. 78.—End View of the Planer.

**Methods of Motion.**—There are two methods in general use for giving motion to the platen of the planer; one, by means of a rack and spur gears; the other is accomplished with a worm and spiral rack. The reverse motion is obtained in either case by the use of open and crossed belts. It is fast becoming a custom, where planers are driven by a motor, to reverse the motor for the backward stroke.

**Comparison to Lathe.**—The planer is not so efficient a cutting machine as the lathe, there being considerable loss of time in every stroke of the platen when returning for the next cut. In the lathe the cutting of the tool is uninterrupted.

**Size.**—The size of a planer is indicated by the height and width of the largest piece of work that can pass between the housings and under the cross rail, and by the length of the platen. Thus, 30-inch by 30-inch by 8-foot planer will plane a piece of work 30 inches square by 8 feet long.

**Explanation of Parts.**—A study of the driving mechanism and the principal parts of the planer can be obtained from the brief description of the numbered parts in Figure 77, which is a side view, and in Figure 78, which is an end view of a planer.

No. 1. The bed is made of cast iron and is quite heavy. It carries the mechanism for moving the platen which is mounted on it.

No. 2. The housings are bolted to the bed and carry the cross rail and its parts.

No. 3. The cross rail's function is to carry the saddle and feed screw.

No. 4. The saddle moves to and fro along the cross rail by means of the feed screw and carries the cutting tool.

No. 5. The Head. The down feed is given to the tool by means of the feed screw which moves the slide that is fitted to the head.

No. 6. The feed screw moves the saddle across the cross rail for feeding the tool or bringing it to the position required.

No. 7. The reverse lever in conjunction with the dogs reverses the direction of the motion of the platen.

No. 8. The dogs can be placed at any position along the side of the platen to regulate the position and length of the platen stroke.

No. 9. The rack extends the whole length of the platen. The large gear or bull wheel which engages

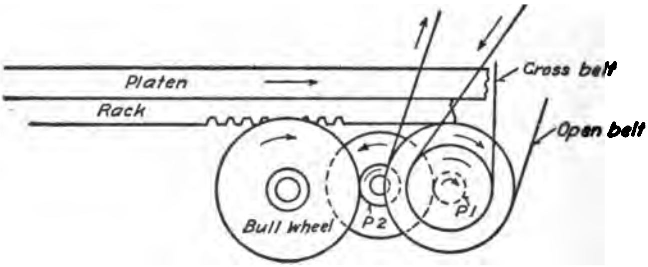



Fig. 79.—Side View of Driving Mechanism.

in the rack moves the platen backward and forward along the ways of the bed.

No. 10. The apron or flapper carries the tool and is hinged on a pin so that the tool can lift on the return stroke.

No. 11. The feed rack gets its movement from the feed disc.

No. 12. The pawl is employed to get different directions of feed.

No. 13. Bevel gears are used for raising and lowering the cross rail.

No. 14. The feed disc revolves a little less than half way around and in connection with the connecting rod gives motion to the feed rack.

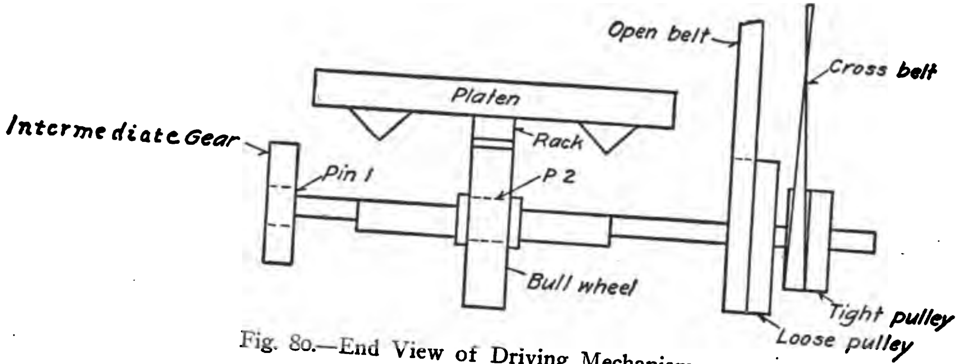


Fig. 80.—End View of Driving Mechanism.

No. 15. To the platen of the planer, the work to be planed is secured, either by bolts and clamps or in a chuck which is fastened to it.

**Driving Mechanism.**—In Figures 79 and 80 are shown side and end views of the driving mechanism. The open belt drives the platen when the tool is cutting; and the crossed belt, when the platen is returning to the starting point of the cut. The small pulleys driven by the cross belt give a quick return to the platen.

There are two pulleys for the open belt, one is keyed to the shaft, the other is loose. The cross belt has the same two pulleys but smaller in diameter. A shifter is provided, operated by arm No. 7 (in Figure 77), which shifts the open belt from the tight pulley to the loose one and at the same time shifts the cross belt from its loose pulley to its tight one and in this way the machine is reversed.

$P^1$ is a pinion keyed to the shaft on which are the pulleys for the open and the crossed belts. This pinion drives the intermediate gear. On the same shaft with this gear is $P^2$, which drives the bull wheel, which drives the rack, which is fastened to the planer platen. In this way the motion is given to the planer for forward and backward strokes.

**Planer Chuck.**—Figure 81 shows a common type of planer chuck. The lugs shown at a, a, are for the purpose of clamping the chuck to the platen by means of bolts. The tongue, b, fits in the slot of the platen and holds the chuck true in any position with the jaws, c, c. The base is circular and is divided into degrees, thus allowing the jaws to be set at any angle with the line of cut. The back jaw, which is loose, is held down by means of bolts. When clamping a partly finished piece of work in this chuck, care must be taken that the movable jaw is lightly clamped before

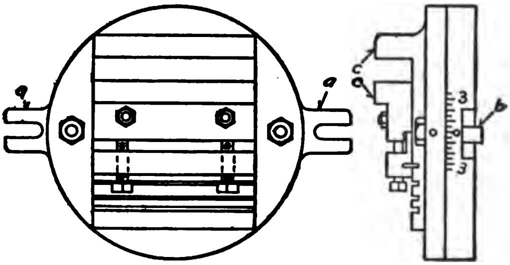



Fig. 81.—Planer Chuck.

the set screws are tightened. If it is not clamped, the result will be as shown in Figure 82. This is a somewhat exaggerated condition, but it shows what will

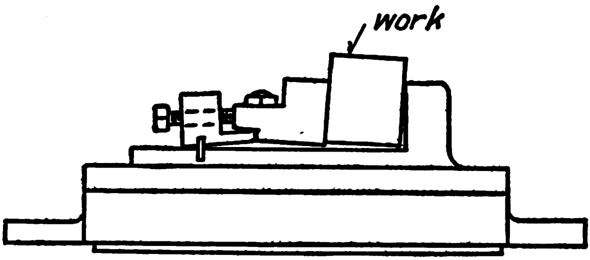



Fig. 82.—Example in Chucking.

happen if the jaws are not clamped lightly before the set screws are tightened.

*Irregular Piece.*—Sometimes a piece of work which is irregular in shape is to be held in the chuck. Care must be taken to clamp it properly. Such a case is shown in Figure 83. Surfaces, a and b, have been planed. Surface, c, is concave. If the jaw is pushed up to this surface, it will catch only on the lower corner and will not get a good grip and at the same time it will tend to tilt the piece. A round or square bar placed, as shown, between the jaw and the piece of work, will push the work up squarely against the tight jaw and not tilt the work.

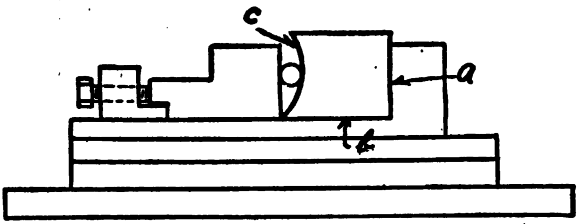



Fig. 83.—Example in Chucking.

*Parallel Strips.*—Parallel strips are thin pieces of steel or cast iron whose opposite faces are parallel. Strips of cold rolled steel are sometimes used for work which is not so important, but where accurate work is desired the strips should be machined perfectly true. These parallels are used for raising the work above the jaws of the chuck; as shown in Figure 84, a-a are the parallels. When parallels are used in this way care must be taken that the work is well down on them. To accomplish this the piece should be clamped lightly and with light blows of a hammer the piece must be driven down until it clamps the parallel strips.

**Fastening Work to the Platen.**—Large pieces of work which cannot be held in place in the chuck must be fastened to the planer platen. This is generally done by clamps and bolts, the heads of the bolts fitting

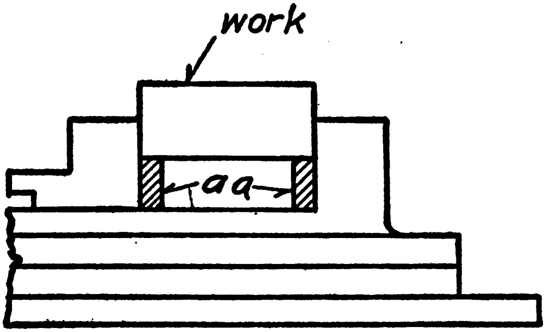



Fig. 84.—Use of Parallel Strips.

in the T-slots of the platen. In Figure 85 is shown a way of clamping a piece which has a lug cast on it. w is the piece to be planed, c the clamp, b the bolt, p

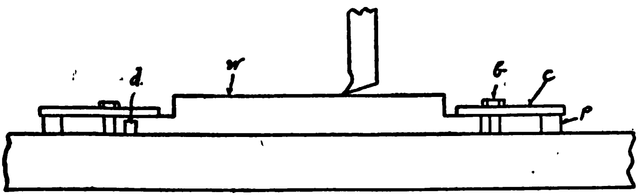



Fig. 85.—Lug Clamping.

the packing block. The clamping bolt, b, should be well up near the work so that *it* will be clamped and not the packing block. The packing block should be as high as the part clamped, better a little higher so that the clamps will press down on the work. If the packing block is lower than the work, the clamp will catch on the corner and not hold the work so well. Stop pins, shown at d, are to keep the work from

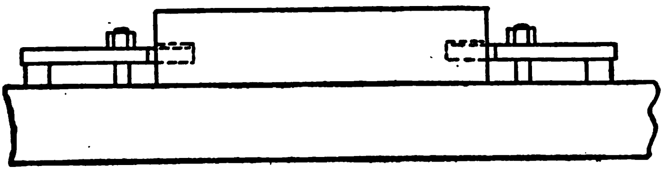


Fig. 86.—Finger Clamps.

sliding when a cut is being taken. These pins are inserted in holes in the platen and when heavy cuts are taken pins at the side with wedges driven in between them and the work will insure the piece's not moving or sliding sideways.

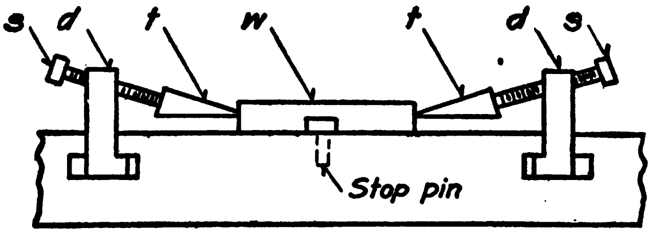



Fig. 87.—Toe Clamps.

When a flat surface is to be planed all over and there is no place to put the clamps except on the top face which is to be planed, the work is planed on either side of the clamps and the clamps are then moved to the place which has been planed. Now the place where the clamps were can be planed. Sometimes it is permissible to drill holes in the work as shown in Figure 86 and to use finger clamps. When this can be done much time will be saved as one clamping will be all that is required to complete the job.

*Thin Work.*—For thin work on the planer, the use of planer pins and toe dogs is an excellent way for holding the work down. This is illustrated in Figure

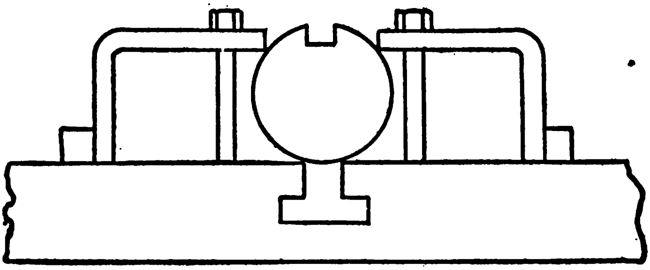


Fig. 88.—Clamping a Shaft.

87 where d-d are the planer pins, t-t the toe dogs, w the work, and s-s the clamp screws. When the screws, s, s, are tightened, they with the toe dogs tend to force the work down on the platen. Stop pins are used at the end to keep it from sliding.

*Keyway in Shaft.*—When a keyway is to be cut in a shaft, the whole length of itself, it can be clamped as shown in Figure 88. The shaft is laid in the center T-slot and clamped down with clamps as shown in the sketch. To keep the clamps from sliding away from the shaft, stop pins are placed at the heel of the clamp. The heel or packing block for this clamp is made one with it. If the keyway does not extend the full length of the shaft, it can be held with ordinary clamps on the top at a place where there is no keyway. Stop pins should be used at the end of the shaft to keep it from slipping when a cut is taken.

*Angle Plate.*—An angle plate is convenient for some classes of work on the planer, such as a flanged elbow

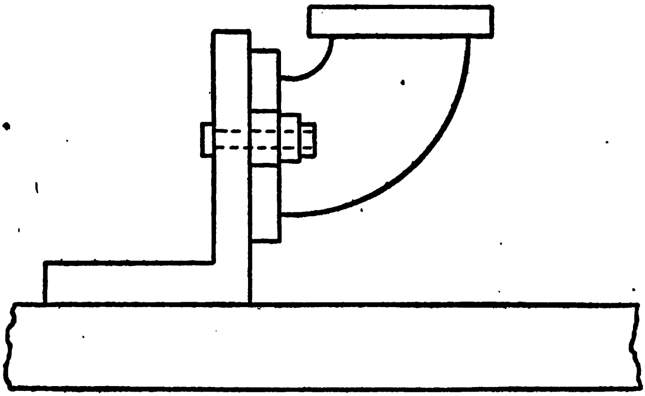


Fig. 89.—Use of Angle Plate.

shown in Figure 89. One flange of the elbow is clamped to the angle plate, and in this position the other flange is planed. After it is planed it can then be bolted to the angle plate and the other flange planed at right angles to the one just completed.

*Fixture.*—When a piece is of such a shape that it is difficult to clamp it to the platen of the planer, it sometimes pays to make what is called a fixture for doing the job. Such a fixture is shown in Figure 90. Here the V's in a tail stock for a speed lathe are to be planed. The round part which surrounds the tail stock spindle is clamped in the V blocks of the fixture. The set screws at the top of the fixture keep the piece from tilting over and also act as adjusting screws to set the piece level. The fixture is bolted to the planer platen. A fixture like this can be made to hold two or

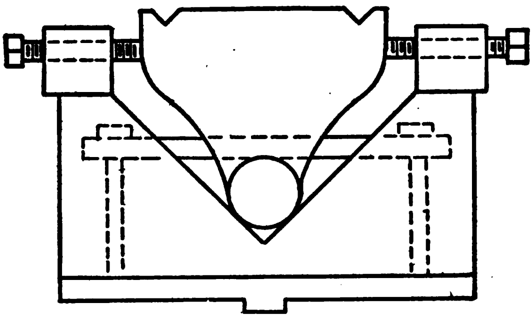


Fig. 90.—Planer Fixture.

more castings, all of which can be planed at the same time.

*Apron.*—When planing flat surfaces which are parallel with the platen of the planer, the tool on the return stroke can be raised, owing to the fact that it is clamped to the apron or flapper which is hinged at one end, thus allowing it to swing out with the tool when the platen is going in the reverse direction to that in which the cutting is done. If the tool were clamped rigidly and could not swing, it would drag on the planed surface and in time wear the keenness off the cutting edge, the fine iron dust acting as an abrasive to the edge of the tool.

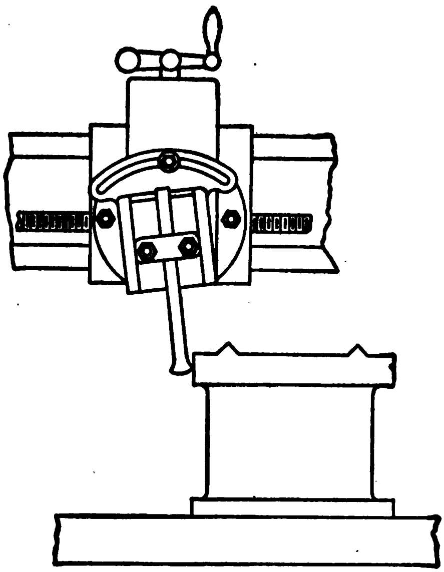


Fig. 91.—Side Planing.

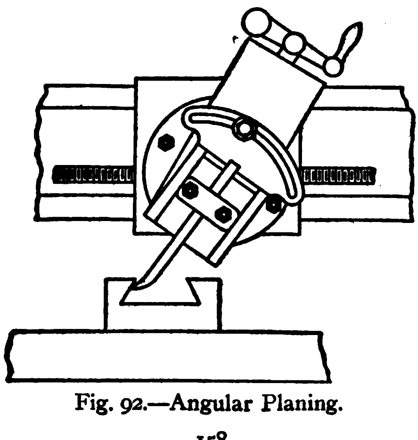


Fig. 92.—Angular Planing.

*Setting of Tool Block.*—When the sides of a casting are to be planed true with the top and parallel with raised portions on it, such as is shown in Figure 91, where a bed plate of a lathe with ways on it is to be planed down the side, the tool block should be swung as shown in the sketch. When swung in this way, the tool will lift away from the work when on the back stroke. If the tool block were set straight, the tool would lift in a vertical line and rub on the return stroke. When an angular cut is to be taken such as a dove tail shown in Figure 92, the head must be swung to the proper angle and the tool block must also be swung as shown in the sketch.

## Shaper

The shaper is practically a small planer. Flat surfaces are produced on both the planer and shaper. The shaper is better adapted for small work because it can be handled faster, its parts being lighter and less cumbersome than those of the planer. Two types of shapers are the "Column Shaper" and the "Traveling Head" shaper. In the column shaper, the work is fed to the tool, while in the traveling head shaper the head is fed to the work.

**Column Shaper.**—Column shapers may be divided into two classes, crank shaper and geared shaper. Figure 93 shows a sketch of a crank shaper, where the principal parts are numbered. A list of the numbers with the corresponding name of the parts follows:

1. Column.
2. Ram.
3. Swivel piece.

4. Down feed slide.
5. Table.
6. Vise or chuck.
7. Vertical slide.
8. Tool block.
9. Cross rail.
10. Cone pulley.
11. Feed arm.
12. Ratchet feed wheel.
13. Saddle.
14. Forward support.
15. Ram clamp.
16. Stroke adjustment.
17. Adjustment for position of stroke.

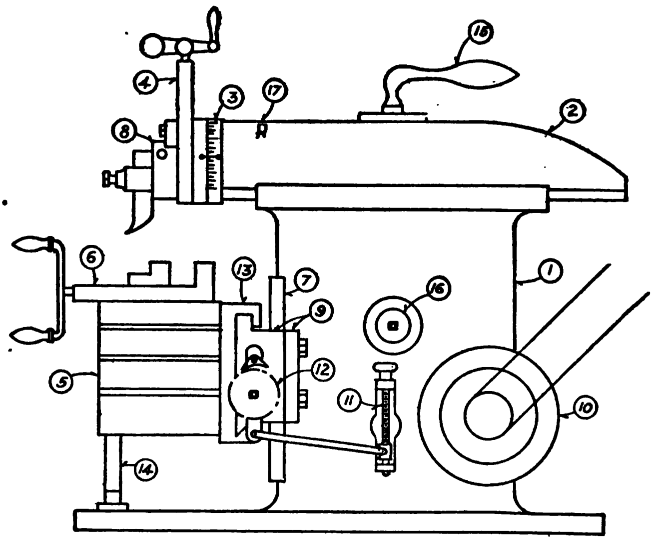



Fig. 93.—Column Shaper.

No. 1. The column with its base carries all parts of the shaper.

No. 2. The ram carrying the tool moves forward and backward for what is called the stroke.

No. 3. The swivel head is used for planing angles.

No. 4. The slide for down feed is always operated by hand.

No. 5. To the table which carries the vise or chucks work can be bolted when too large to be placed in the chuck.

No. 6. The vise can be swung around to any position.

No. 7. On the vertical slide the cross rail fits and can be moved up or down.

No. 8. This is arranged exactly like the planer tool block with this exception: a tool post is generally used instead of a clamp which is used on a planer.

No. 9. The cross rail carries the saddle, table, and the vise, and can be moved up and down on the vertical slide to bring the work to the tool.

No. 10. The cone pulley is for the purpose of obtaining different speeds.

No. 11. The feed arm oscillates to give motion to the feed rod which works the pawl on the ratchet feed wheel.

No. 12. The ratchet feed wheel. When the arm, No. 11, moves the ratchet carrier, the ratchet wheel by means of the pawl is rotated a small amount, thus giving a part of a turn to the feed screw which feeds the saddle across the cross rail.

No. 13. The saddle carries the parts on which the work to be planed is fastened.

No. 14. The forward support keeps the table from springing down when the pressure of the cut comes at the outer end of the stroke.

No. 15. The ram clamp is for clamping the ram at the desired position of stroke.

No. 16. Adjustment for different length of stroke.

No. 17. Adjustment for the position of stroke.

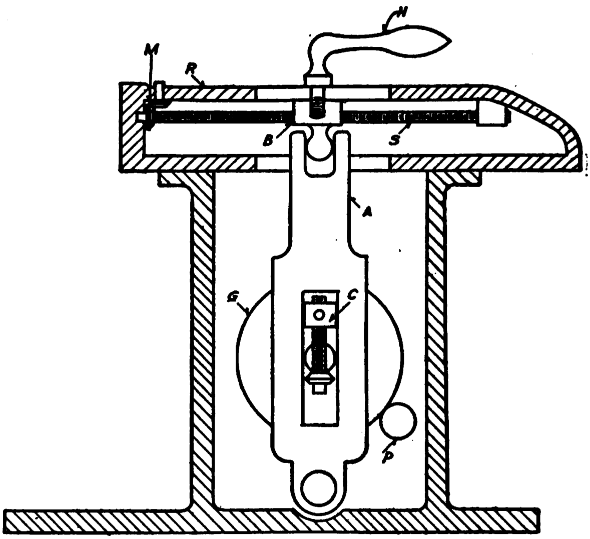



Fig. 94—Vertical Section.

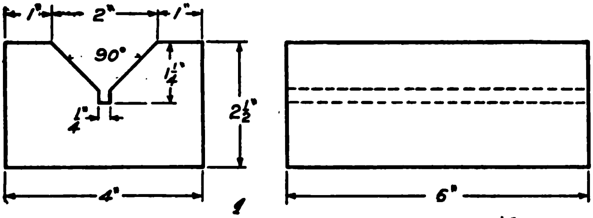
*Vertical Section.*—In Figure 94 is shown a vertical section through the center of the shaper, shown in elevation in Figure 93. In this sketch, P is the pinion which is fastened to the cone pulley shaft and drives the large gear G. On this gear, G, is mounted a block, C, which can be moved into and out from the center of the large gear. This block acts as a crank pin to the arm, A, which gives motion to the block, B. The block, B, is secured to the ram, R, and by means of the miter gear, M, and the screw, S, which passes through the block, B, the position of the stroke can be brought to the proper place.

The work done on a shaper is held and operated on in exactly the same way as on a planer, which has been explained in this chapter.

## QUESTIONS ON CHAPTER IX

1. For what is a planer used?
2. What other machines are modifications of the planer?
3. What is the difference between right and left hand tools for the lathe and planer?
4. Which is the more efficient cutting machine, the lathe or the planer and why?
5. What is the difference in the feed as regards the movement of the work and the tool in a shaper and in a planer?
6. What two methods are generally used for giving motion to the platen of the planer?
7. How is the reverse motion obtained?
8. How is the size of a planer designated?
9. Name 10 of the principal parts of a planer.
10. State three different ways of fastening work to a planer.
11. What are parallel strips?
12. What are parallels used for?
13. When fastening work to the planer with bolts and clamps, why should the bolt be close to the work rather than to the packing block?
14. What should be the height of the packing block in relation to the work?

15. For what are stop pins used?
16. What is a finger clamp and what is a planer pin?
17. What are toe dogs? Describe how they are used.
18. What is the name of the piece of apparatus which should be used with the planer to plane a flanged elbow?
19. What is a fixture?
20. Why is the planer tool left free to swing out on the reverse stroke? How is this swing accomplished?
21. Why should the tool block be swung at an angle when planing down the side of a piece?
22. Name 10 of the principal parts of a crank-driven column shaper.
23. What is the difference between the methods of holding a tool in the planer and in the shaper?
24. Why is the shaper better adapted to small work than the planer?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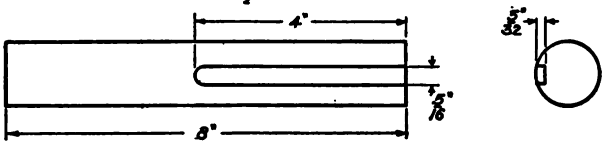
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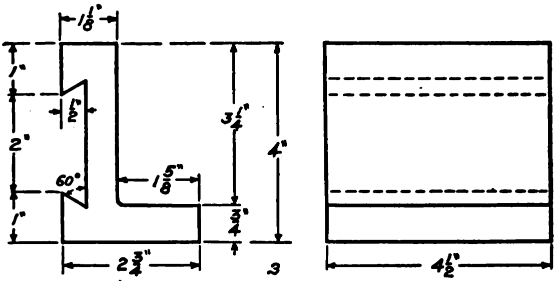
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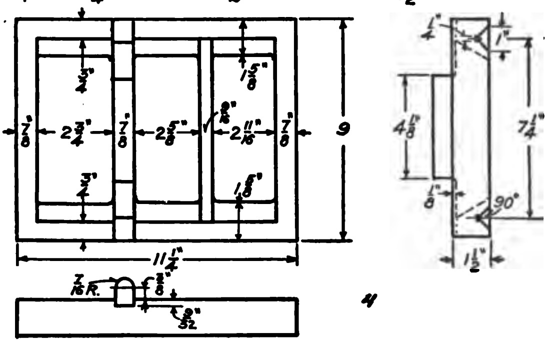
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1/8"
90°
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4

# CHAPTER X

## BORING MILL

**Vertical.**—There are, generally speaking, two classes of boring mills; namely, the vertical and the horizontal. The vertical is made in sizes from thirty inches to thirty feet and is virtually a face plate lathe with the tail stock omitted. As the boring mill is built much heavier than the lathe, it is a better machine for doing heavy work.

The fact that the face plate is horizontal, makes it easier to adjust the work when fastening it to the machine. There are no overhanging parts. Gravity also assists in holding heavy pieces to the plate.

*Parts.*—A turret head is usually provided on small-sized machines and there are automatic feeds in all directions on both large and small mills. Large vertical boring mills are made so that the housings can be moved back from the center of the table, thus allowing a larger piece to be turned than the regular size of the mill permits. When this is the case, an extending arm must be provided for boring and turning the hub which can be done while the outside portions of the work are being machined.

*Ram.*—A large boring mill generally has the ram arranged with a quick up and down motion for the purpose of cutting keyways in the hubs of large wheels,

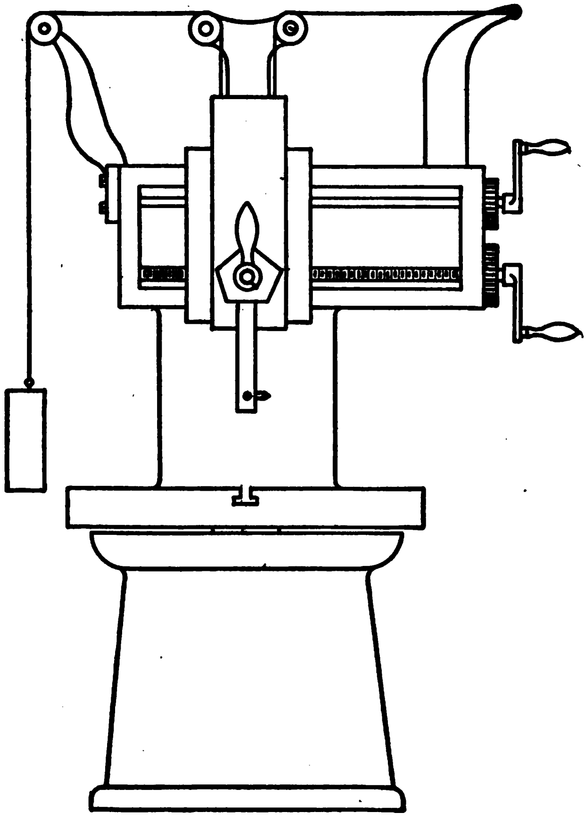


Fig. 95.—Vertical Boring Mill.

cranks, etc., thus saving the time of handling and resetting the work on a keyseating machine.

When clamping work to a boring machine, the same

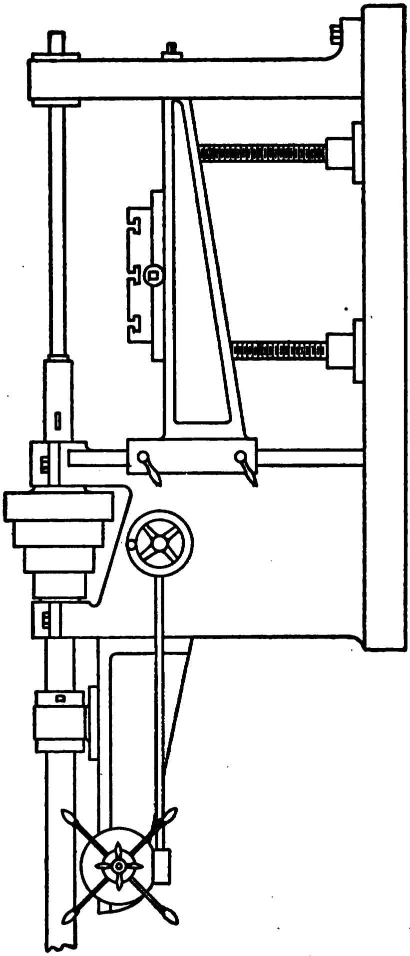


Fig. 96.—Horizontal Boring Mill.

precaution must be taken as when clamping to the face plate of a lathe or to the platen of a planer.

*Tools.*—The tools used on boring machines are similar to those used on the lathe and the planer.

**Horizontal.**—The horizontal boring mill is also made in large and small sizes which are excellent for a general line of work owing to the fact that they can be adapted to a large range of work.

*Spindle.*—The spindle is in a horizontal position and

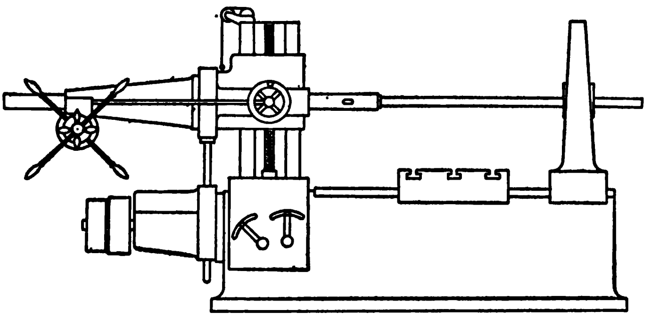


Fig. 97.—Horizontal Boring Mill with Vertical Movement of Spindle.

operates very much like the spindle of a drill press. On some machines, the spindle is mounted in immovable bearings and the table of the machine is adjustable in three directions, thus making it possible to bring the work to any position to be operated on by the tool which is held in the spindle of the machine or in a boring bar.

The screws which operate these movements are provided with graduated dials, thus making it possible to get exact spacing for holes in the work being done.

*Another Type.*—In another form of boring mill the work table is mounted on the bed and has no vertical movement, but the spindle is arranged to move vertically on the uprights. The outer bearing moves automatically with the spindle, thus keeping it in line.

In Figure 95 is shown a vertical boring machine and in Figure 96 one type of horizontal; and in Figure 97, another type of the same.

*Uses.*—The horizontal boring mill can be used for a large variety of plain milling, the milling cutters being held on an arbor in the spindle of the machine;

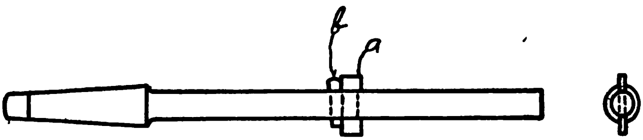



Fig. 98.—Boring Bar.

and for heavy face milling the cutter is sometimes bolted to the spindle directly.

*Cylinders.*—Single cylinders and those cast together can readily be bored on the horizontal machine as one clamping is sufficient for all the bores. In case several cylinders are cast together it is only necessary to use the cross movement of the table for the successive settings of the different cylinders.

**Boring Bar.**—A boring bar, as shown in Figure 98, can be used to advantage on the vertical mill. The tapered shank is inserted in the head of the machine. It is driven by the tang at the end of the shank. A rectangular slot is made at about the center of the bar and a cutter is fitted in as shown at a. The key, b, holds the cutter in place when driven in tight. Sometimes the cutters are single-ended and are held with a set screw in the side of the bar at right angles to the slot. The end of the bar opposite the shank end fits in the hole in the center of the table making it quite rigid.

Another style of boring bar is shown in Figure 99. This bar can only be used on a horizontal boring mill or on a lathe. It is sometimes made of cast iron, cored out so as to secure the greatest stiffness with the least weight. A shows the head which carries the cutting tools. This fits neatly on the bar which is turned parallel. The head is moved along the bar by means of

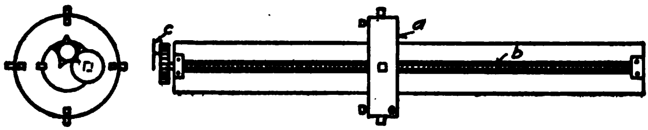



Fig. 99.—Traveling Head Bar.

the screw, b. A nut is fastened to this head and is free to move in the slot in which the screw is mounted. On the opposite side of the bar from the slot is a keyway in which slides the key that drives the head. The bar is mounted by attaching it either to the spindle of the boring mill or between the centers in the spindle and the outer bearing. Sometimes it is mounted in special bearings and driven by gears. A star feed, shown at c, rotates the screw to feed the head along the bar.

**Setting of the Work.**—The horizontal table of the vertical mill makes the setting of the piece of work different from that of the lathe and somewhat like the setting upon the drill press. The piece must be set perfectly central with the center of rotation of the spindle, as in the lathe, and must be blocked up and clamped in the same manner as on the drill press or must be held in the jaws of a chuck as is done on a lathe.

The face must run true and must be blocked up at the low places. Heavy pieces should be driven by one or more drivers to prevent the piece from shifting when the cut is applied. Nearly anything can be used as a driver; small angle plates are convenient. These are placed against some radial part of the work, such as the arm of a flywheel, and are clamped to the table. Sometimes heavy bars, placed at some projecting point and wedged tight, are good.

In clamping pieces to the horizontal mill, if the piece has been planed and the bore is to be parallel to this planed part, the setting becomes somewhat simple. The machine is built true and, if the piece is set on the planed part, resting on the table of the machine, it will remain true in that direction while the settings in the other direction are being done.

**Boring of Cylinders.**—Cylinders which are to be in a vertical position when in operation should always be bored in a vertical position, and those that are to be in a horizontal position when in operation should be bored in a horizontal position. This, of course, applies more directly to large and heavy work. For small work it is not so important that this custom be followed.

**Difference in Methods.**—On the vertical mill, the work is clamped to the rotating table and revolves while it is being worked upon either for boring or for turning. This is not the case with the horizontal mill. Here the work is fastened down to a plate or table and a bar carrying a cutting tool rotates and is fed along to the work. Both methods have their merits. In the case of the first, a large flywheel is to be turned and bored. It is more convenient to rotate the flywheel and to have the tool work on the outer diameter than it would be to have the tool travel around the rim of the wheel. It is evident that the vertical mill is the better machine on which to do this job.

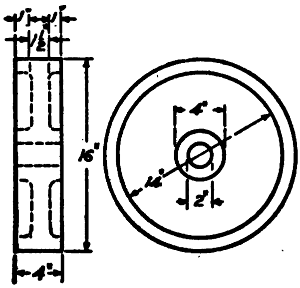
Again, take the case of a large cylinder with projections on it, such as valve chambers. To set this cylinder down on a plate and have a boring bar with a traveling head rotating in the center of it is obviously the better way to do this job, since the moving parts are light and, therefore, less power is needed to operate them. This job can better be done on the horizontal mill because a bar with a traveling head is better for boring cylinders and this bar can be used to the best advantage on the horizontal machine. A bar with a fixed cutter must be at least twice as long as the cylinder being bored, while the traveling head bar need be only a little longer than the cylinder.

## QUESTIONS ON CHAPTER X

1. What are the names of the two kinds of boring mills?
2. What kind of work is done on a boring mill?
3. Why are some vertical mills arranged to have the housings moved back?
4. When this is done, what extra piece must be provided and for what purpose?
5. How can keyways be cut in the hubs of large wheels on a boring mill?

6. What is the purpose of the graduated dials on the feed screws of a horizontal boring machine?
7. What, besides boring, can be done to advantage on the horizontal mill?
8. Describe the construction of two kinds of boring bars.
9. Why is a cast iron bar better than a steel one?
10. What two principal things must be observed in setting a piece of work on the vertical mill?
11. Why are drivers employed for heavy work on a boring mill?
12. If a cylinder is to operate in a vertical position, on which boring mill should it be bored?
13. Why is a vertical mill a better machine on which to turn a large flywheel?
14. Why is a horizontal machine better for boring large cylinders?

## EXERCISES FOR PRACTICE

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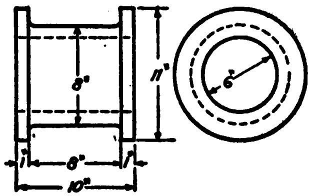


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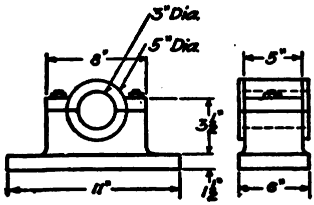


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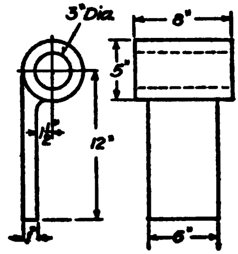


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# MACHINE SHOP PRACTICE

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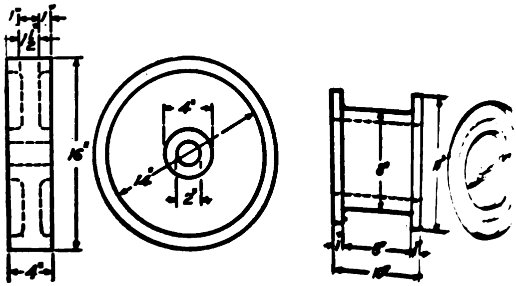
## EXERCISES FOR PRACTICE





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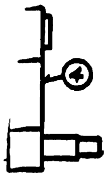

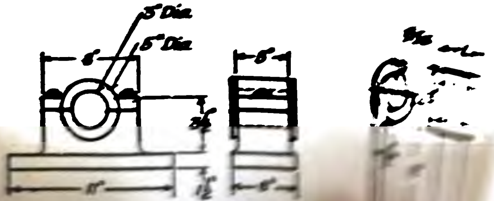



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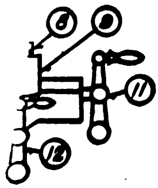

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## CHAPTER XI

### MILLING MACHINE

The milling machine differs from the lathe and the planer in that the metal is removed by a rotary cutter. The work is fed to the cutter but does not revolve as in the lathe. A greater variety of work can be done on the milling machine than on the shaper or the planer. This is due to the peculiar adaptability of the rotating cutter.

**Skill.**—Less skill is required in the manipulation of the milling machine than in that of the shaper or the planer, due to the fact that on the planer and the shaper all measurements must be made separately because the tool generates the profile of the work by a series of parallel cuts, all changes in the shape of the profile requiring separate measurements and adjustments, whereas with the milling machine the cutter is so formed as to produce the proper profile of the work surface as it is fed to the cutter. When the work is once set, the formed cutter can be run over it and it is finished.

**Classes.**—The general classification of milling machines are universal, plane, vertical, slab, and hand.

The universal machine is one on which all kinds of milling work can be done. The plane is one on which only plane milling can be done. Sometimes, however, with special attachments other than plane milling is accomplished. The vertical is a plane milling machine with its spindle in a vertical position and most of the work done on it is done with an end mill. The slab

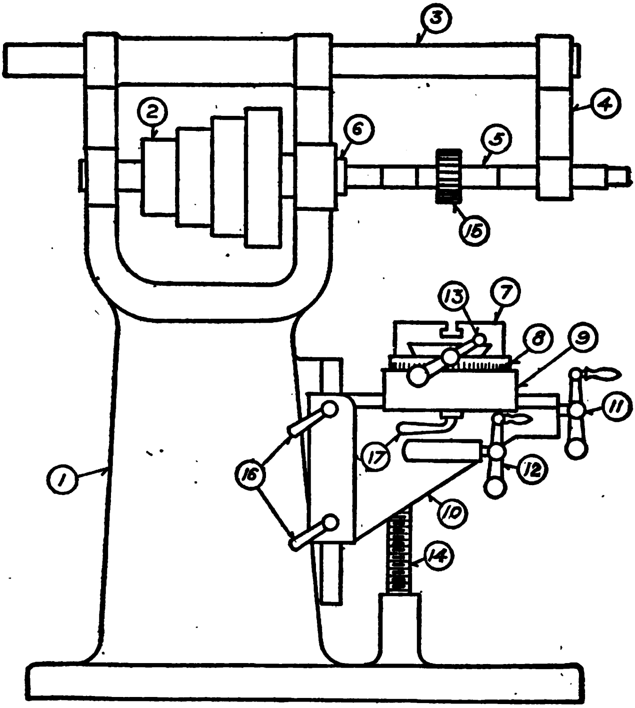


Fig. 100.—Universal Milling Machine.

is designed for doing heavy work and is constructed differently from the plane or universal. The hand is one where the feeds are given to the work by hand.

**Universal.**— In Figure 100 is shown a sketch of a simple universal machine. Here only the principal parts are shown and numbered as follows:

1. Column of machine.
2. Cone pulley.
3. Over arm.
4. Outer bearing for arbor.
5. Arbor.
6. Spindle.
7. Table.
8. Swivel base.
9. Saddle.
10. Knee.
11. Cross feed.
12. Vertical feed.
13. Longitudinal feed.
14. Vertical feed screw.
15. Plane milling cutter.
16. Knee clamps.
17. Saddle clamp.

No. 1. The column is one with the base and carries all parts of the machine.

No. 2. The cone pulley rotates the spindle of the machine. In the larger machines a back gear is provided, similar to that on a lathe.

No. 3. The over arm is provided to support the outer end of the arbor in order to make it stiffer.

No. 4. The adjustable outer bearing in which the arbor rotates.

No. 5. The arbor carries the cutters for different milling operations.

No. 6. The spindle of the machine.

No.7. The table or platen on which are placed the dividing head and the tail center.

No. 8. The swivel base is provided only with universal machines.

No. 9. The saddle carries the swivel base and table.

No. 10. The knee is a heavy casting in the form of an angle plate and can be moved up and down to bring the work to the cutter. The saddle moves in and out on this knee to locate the work or feed it to the cutter in the in-and-out direction. The table moves on the saddle in the opposite direction to feed the work to the cutter.

No. 11. The cross feed.

No. 12. The vertical feed.

No. 13. The longitudinal feed. All these feeds may be operated by power. All the larger machines have power feeds.

No. 14. The vertical feed screw.

No. 15. A plane milling cutter. This is placed on the arbor which is capable of receiving different shaped cutters.

No. 16. The knee clamp.

No. 17. The saddle clamp.

**Milling.**—Milling is done with a rotating cutter having a number of teeth so formed as to suit the work in hand and tempered to suit the nature of the material to be operated on. On large work, the cutters are provided with what is called inserted teeth. The body of the cutter is made of some inexpensive material, such as cast iron, which can be used continually, the teeth being made of tool steel which can be reground and, when too small, can be made new.

**Milling Cutters.**—Before entering into the study of work on a milling machine, a description of a few of the common milling cutters in use will be advantageous. The names of the principal milling cutters are the plane cutter, or one which produces a plane

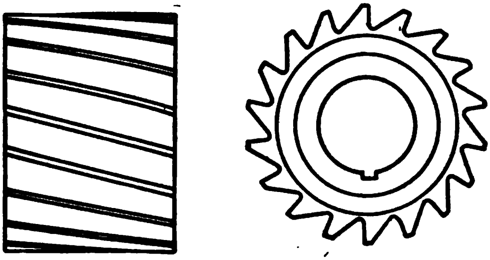


Fig. 101.—Plane Milling Cutter.

surface only, Figure 101; the end mill cutter, which has teeth on its end and is capable of producing a surface with these teeth, Figure 102; the side mill, sometimes called straddle mill, which is provided with teeth on both faces, Figure 103. In Figure 104 is

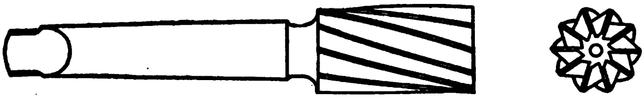


Fig. 102.—End Milling Cutter.

shown an angular cutter provided with face teeth. In angular work, where the end mill action is not required, the teeth on the face are omitted and the face is ground slightly concave.

**Formed Milling Cutters.**—With a variation of size and shape of these cutters, a wide range of work can be done, but for a considerable variety of work the

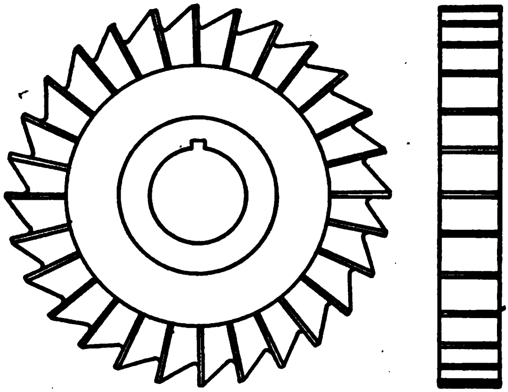


Fig. 103.—Side Milling Cutter.

formed mill must be employed. A few of these are as follows:

The standard T-slot cutter, Figure 105, is used for

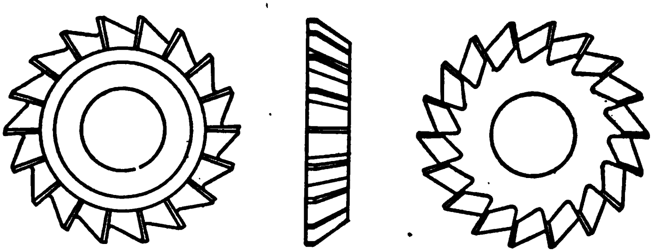


Fig. 104.—Angular Milling Cutter.

finishing the slot as shown in Figure 106. In Figure 107 is shown a gear cutter for forming the teeth of gear wheels. In the backing off or relieving of this cutter, its original form is retained and it will cut the

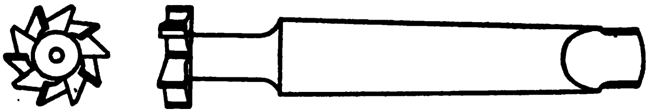


Fig. 105—T-Slot Cutter.

teeth of a gear correct in shape until it is ground down as thin as its cutting teeth will stand. In Figure 108 is shown a circular corner cutter, sometimes

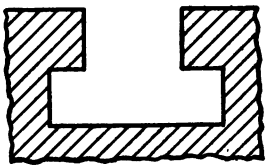


Fig. 106.—T-Slot.

called a radius cutter. The hob cutter for hobbing worm wheels is shown in Figure 109. There are

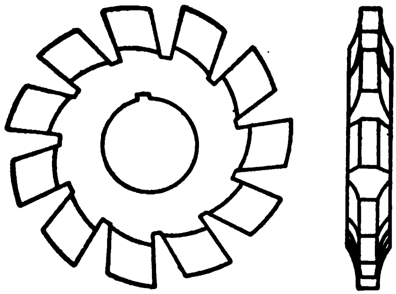


Fig. 107.—Gear Cutter.

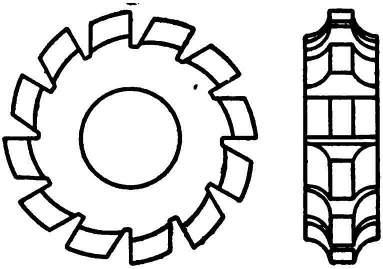


Fig. 108.—Radius Cutter.

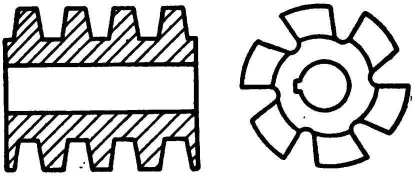


Fig. 109.—Hob.

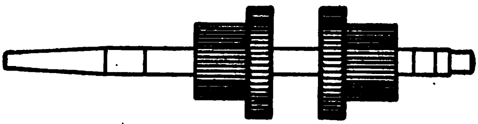


Fig. 110.—Gang Mill.

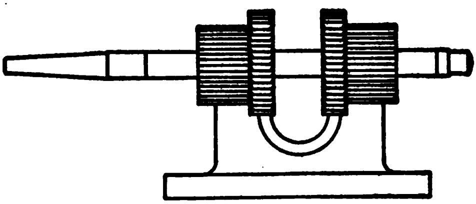


Fig. 111.—Gang Milling.

many other formed cutters made to suit the work in hand, but they are too numerous for illustration.

**Gang Milling.**—Another method of forming shapes is the use of what is known as the gang mill. This is shown in Figure 110. Here four cutters are used on an arbor to mill the pillow block as shown in Figure 111. This gang mill with one traverse over the work will finish and properly form the top of the pillow block. To do this on a planer or shaper would take several measurements and settings of the tool. The gang mill is economical at times for the production of only one piece, where there are several pieces, it is still more economical.

**Common Milling Machines.**—The plane and universal milling machines of the column type are used in shops and tool rooms. In Figure 100 is shown a simple universal machine without back gear. The power-feed mechanism is omitted to avoid complication in studying the construction.

**Milling Work.**—The work is placed on the table, 7, and is clamped to it or held in a vise which is bolted to the table. Some work is held between centers by using the dividing head and the tail center, which will be explained later. The arbor, 5, is made in different lengths and sizes to carry the proper cutters. The spindle, 6, is driven by the cone, 2. The arbor, fitting in the spindle with a taper fit, rotates the cutter while the work is fed to it.

*Feeds.*—The hand longitudinal feed is operated by the handle shown at 13. This can be operated by power. The cross or in-and-out feed is worked by the handle shown at 11 and has power-feed connection. The vertical or up-and-down feed is operated by the handle shown at 12. This also is connected to the power feed. All these feeds are provided with graduated discs divided to read to thousandths of an inch. These discs are adjustable and can be set at any position, thus making it possible to take 1/1000 or 1/32 of an inch deeper cut, if desired; or, in cutting grooves, the spacing of them can be done very accurately without the use of a rule.

*Knee.*—The knee, shown at 10, is made quite heavy and rigid. The vertical feed screw, 14, acts as an outer support to the knee which is gibbed to the column. When the machine is cutting, it can be clamped to the column by the clamps shown at 16.

*Milling a Helix.*—When a helix is being milled, the table must be swung at an angle corresponding to the helix angle. This can be done by the swivel base shown at 8.

**The Dividing Head and the Tail Stock.**—The dividing head and the tail stock are two very important parts of a milling machine, more especially the dividing head. In Figure 112 is shown a universal dividing head and tail stock. The parts are lettered. a is the driver or face plate. It is secured to the center and when the center is removed it comes out with it. b is the spindle which can be rotated by means of the index pin, g. j is one of the clamps for driving a straight-tailed dog (another one is just back of this). c is an index plate for the rapid spacing of the most commonly used divisions, such as squares, hexagons, octagons, etc. d is the head which carries the spindle. This is mounted in a circular guide of the frame, e, and may be rigidly clamped in any position within the range of movement which is about 10 degrees below the horizontal and ten degrees beyond the vertical positions. f is one of the index plates for fractional turns which are furnished with the head. g is the index pin which is used as a crank for rotating the spindle of the head. h is the sector for locating the positions of fractions of whole turns of the index pin, and s is the tail stock or tail center. Inside the head,

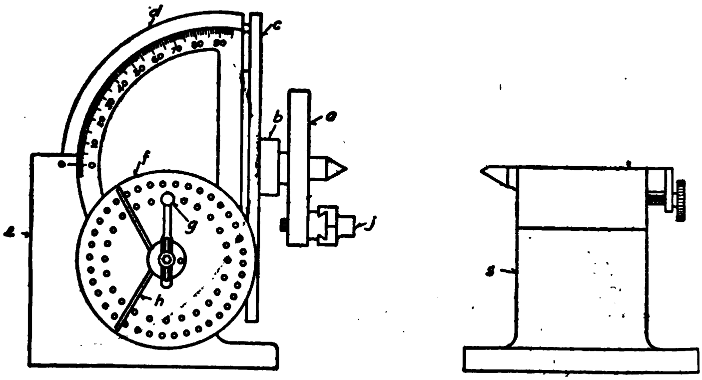



Fig. 112.—Dividing Head and Tail Stock.

mounted on the spindle, is a worm wheel with 40 teeth. This worm wheel is rotated by a single-threaded worm. Forty turns of the worm rotates the spindle one turn.

*General Arrangement.*—The general arrangement of this is shown in Figure 113. Here w is the worm wheel, s the worm, e the frame, b the spindle of the head, f the index plate, g the index pin and crank, and h the sector.

If the worm wheel has 40 teeth and is rotated by a single-threaded worm, it will take 40 turns of the worm to make one turn of the worm wheel which is fastened to the spindle and will consequently rotate the spindle one at the same time. To rotate the spindle half way around will take 20 turns of the worm and to rotate it one quarter will take 10 turns, and so on. To find the number of turns, place the number 40 above the line and the number of divisions desired

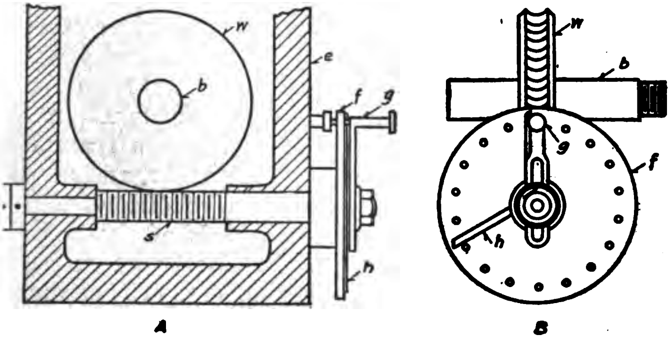



Fig. 113.—Section of Dividing Head.

below; thus, 40/2 equals 20 turns; 40/4 equals 10 turns; 40/8 equals 5 turns.

The whole turn can be gauged either by marking a certain hole on the index plate or by placing one of the arms of the sector at a certain hole and bringing the index pin to this hole at each revolution, also using this hole as a fixed stop for the index pin.

**Indexing.**—The turning of the spindle one-half, one-quarter, etc., is called indexing or spacing. If two flats are to be milled on the opposite sides of a cylindrical piece which is between the centers, the first one would be milled and the piece indexed or spaced one-half way around and then the next flat is milled. The same is done with a square, except that the spacing or indexing is on quarters each time.

*Indexing for the Milling of a Hexagon.*—In some indexing it is necessary to give the worm whole turns and a part of a turn. When spacing for the milling of a hexagon this is true. Thus 40/6 equals 6 2/3 turns. For the milling of each flat the spacing must be done by giving the worm 6 2/3 turns. For cases like this the index plates f are provided. These plates have rows of holes at different distances from the center. The first row nearest the center naturally has fewer holes than the outside one. Where a fraction of a turn is necessary, such as 6 2/3 turns, an index plate with a row of holes that can be divided into thirds must be selected and two-thirds of the holes must be used for locating the fractional part of the turn. This is shown at B in Figure 113. The sector, h, must be set with one arm at the index pin, the other arm just uncovering the twelfth hole from this point. There are 18 holes in this row on the plate. When counting for the fraction of a turn the hole containing the pin must *not* be counted, as it is spaces that are required. The sector saves the time of counting the required number of holes each time.

*Operations of Indexing for a Hexagon.*—The operations of indexing for a hexagon are as follows: Select an index plate with the required number of holes. In the case of a hexagon 18 will do, as 18 can be divided into thirds. Place the index pin in any one of these holes with one arm of the sector against it, count off twelve holes (not counting the one containing the pin), place the other arm of the sector just uncovering the twelfth hole, and clamp the arm of the sector in this position.

After the first cut has been taken over the piece, return the cutter back of the starting point. Now turn the index crank six whole turns and the twelve holes or two-thirds of a turn. The sector must now be rotated until the first arm is against the index pin. The second cut can be taken and the operation repeated until all sides of the hexagon are completed. A plain milling cutter can be used for this piece of work.

In some cases less than a whole turn is required to give the proper indexing, such as in spacing a gear wheel with 52 teeth; then 40/52 or 20/26 or 10/13, any of these ratios, will give the proper indexing. The first would require an index plate with 52 holes when 40 holes must be taken each time, or one with 26 holes when 20 are taken each time, or one with 13 holes when 10 are taken. It is possible that none of these plates are available; if so, the smaller ratios can be increased. The ratio 10/13 can be raised to 30/39, which is also correct; then, the indexing will be 30 holes on the 39 circle.

## QUESTIONS ON CHAPTER XI

1. How does the milling machine differ from the lathe and the planer?
2. Why can a greater variety of work be done on the milling machine than on the shaper or the planer?
3. Why is less skill required in the manipulation of the milling machine than in the use of the shaper and the planer?

4. Give the general classification of milling machines and a brief description of each.
5. What is the purpose of the column?
6. Why is the over arm provided?
7. What kind of cutters are used for plane milling?
8. Describe the construction of an inserted tooth cutter.
9. State the names of four different milling cutters.
10. What is a formed milling cutter? Name three kinds.
11. Why is the original shape of formed milling cutters retained in the releasing or backing off?
12. What is meant by gang milling?
13. Is the gang mill economical?
14. How is the work held in the milling machine?
15. For what purpose is the arbor of a milling machine?
16. Why are graduated discs provided on all the feeds of the milling machine?
17. Why is the swivel base provided on the universal machine?
18. How many teeth are in the worm wheel in the dividing head?
19. How many turns of the worm are required to rotate the spindle one turn?
20. How many turns of the worm will rotate the spindle ¼ around?
21. What is the purpose of the index plate?
22. What is indexing or spacing?
23. What is the proper indexing for a piece with 4 sides? with 8 sides?
24. What is the proper indexing for a piece with 6 sides? with 12 sides?
25. Give the proper indexing for a wheel with 24 teeth? for one with 40 teeth? and for one with 49 teeth?
26. For what purpose is the sector provided?

# CHAPTER XII

## MILLING MACHINE WORK

**Cutting a Keyway.**—A keyway is to be cut in a shaft as shown in Figure 114. The shaft has been turned in the lathe and has centers in it. Place a straight-tailed dog on the place which is not to have any keyway and put the piece between the centers of the machine. The clamps, j, must be brought together

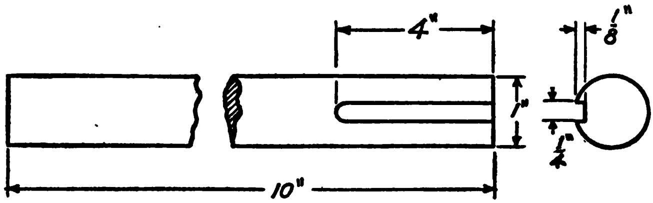



Fig. 114.—Milling Exercise.

against the tail of the dog to keep the piece from rotating. In the lathe the tail of the dog is free to rotate a little, but in the milling machine work it must not rotate. The action of the tool in the lathe is always in one direction while in the milling machine the cutter acts in different directions; again, the piece must be held rigid to give the true form of the cutter. A quarter-inch end mill can now be placed in the spindle of the machine and the knee brought up until the centers of the spindle of the machine and of the dividing head are in the same horizontal plane. This can be done by a mark which is generally placed on the slide where the knee moves up and down on the column of the machine. The cross feed can now be fed in until the face of the end mill has passed in beyond the outer diameter of the piece ⅛ of an inch, the piece being run back so that the mill does not touch it at the tail stock end. With the end mill rotating, the cut can be run along for the 6″ required and the keyway is completed.

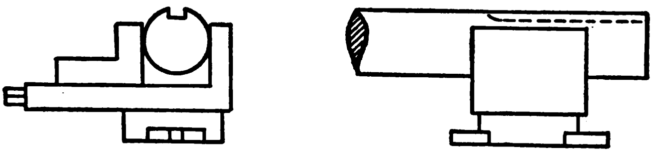


Fig. 115.—Use of Vise.

This keyway could be cut by a side mill shown in Figure 103 where the shaft is held in the vise as shown in Figure 115. When done in this way, however, the keyway will not have the full depth at the back end due to the large diameter of the side mill. The latter way is the better, provided the keyway can be made a little longer in order to get the full depth of the keyway as far as required or the curved part of the groove can be finished with a chisel. Small end mills are rather fragile and should only be used where other cutters will not answer.

**Cutting a T-Slot.**—When cutting a T-slot as shown in Figure 106, the piece can be held in the vise and the T-slot cutter can be used in much the same way as the end mill. If the machine is provided with a vertical attachment, the piece can be clamped to the table of the machine and the cutter can be held in a vertical position in the vertical spindle. The latter is a better way as the operator can observe the work better when it is lying flat on the table.

**Centering of the Cutter.**—It is sometimes necessary to have the center of the cutter in the same vertical plane passing through the centers of the spindle of the dividing head and the tail center. When cutting the

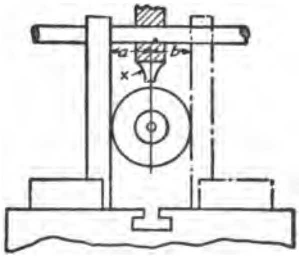



Fig. 116.—Centering of the Cutter.

teeth in a gear wheel this centering of the cutter is absolutely essential and can be done as follows. Place the mandrel with the blank on it between the centers with a dog on the end of the mandrel as described before for milling the quarter-inch keyway in Figure 114. After the work has been placed in the machine, with the in-and-out feed, bring the work until the cutter is approximately in the center. Now placing a square on the table as shown in Figure 116 and pushing it up until it touches the outside diameter of the wheel, measure the distance, a; then, place the square on the opposite side in the same manner and measure the distance, b. When a and b are equal, the cutter is in the center of the work.

Some gear cutters have a fine line marking the center. If there is no line, the side of the cutter at a point, x, on one side and a corresponding point on the other side of the cutter can be used instead. If the cutter is symmetrically formed, the side faces can be used.

In Figure 117 is shown another fairly accurate way of setting the cutter centrally. This is a top view of

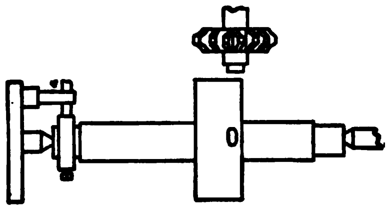



Fig. 117.—Centering of the Cutter.

the work. After the work has been placed between the centers as shown, it is brought up until the cutter just touches it lightly and, with the cutter revolving, the cross feed is run in and out making a small spot on the top of the work. The cutter is now set so that it cuts through the center of this spot.

**Milling a Split Nut.**—The piece shown in Figure 118 is a split nut for a lathe. It has been cast in one piece and is to be split after it is machined. The surfaces a-1, a-2, a-3, are to be milled. The threaded part has been done on a lathe and a mandrel has been provided to hold the piece between the centers of the milling machine. A jack placed under the piece and a

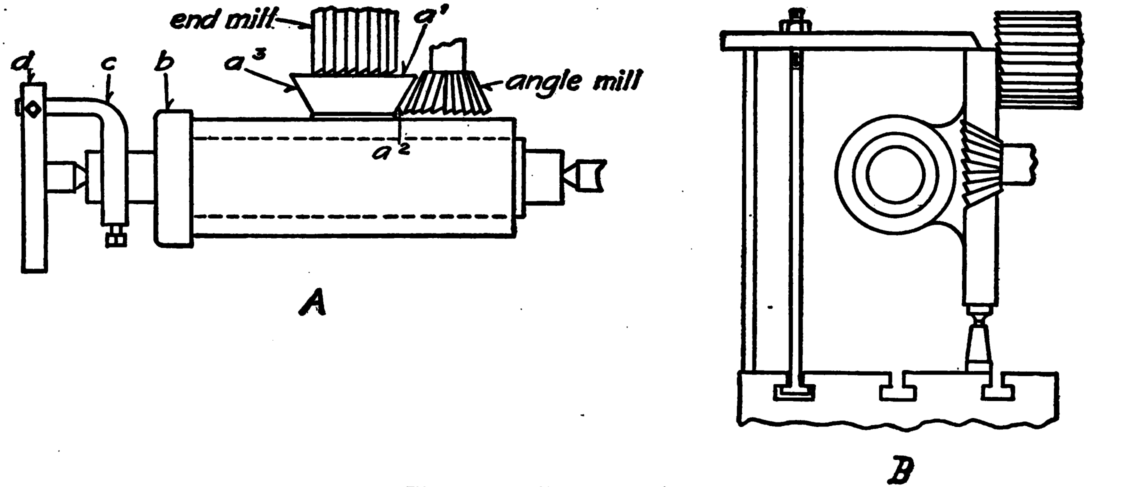



Fig. 118.—Milling Exercise.

clamp used as shown at B in Figure 118 will keep the job from turning on the mandrel. With an end mill, mill the surface, a-1, to the proper dimension from the center of the mandrel. Next, mill up and down on the sharp corners of the dovetail until surface, a-1, is the proper width. Now with an angle mill of the proper angle the sides can be milled.

**Direction of Feed.**—As there is always some lost motion in all feed screws, the cutter must always be fed in the proper direction; that is, the work should be fed against the cutter. At a in Figure 119, if the

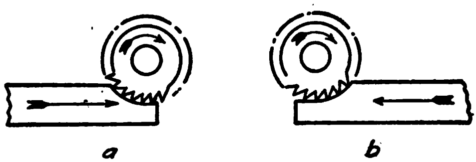



Fig. 119.—Feed Direction.

cutter is rotating in the direction of the arrow, the work should be fed in the direction of the arrow as shown. If the work is fed in this way, the cutter has a tendency to push it away from the cutter and not to draw it in. If the work is fed as shown at b, there is a tendency to draw the work to the cutter and make it dig in, and either the cutter will be broken or the arbor will be bent.

Feeding *with* the cutter can be done on a machine specially designed for doing so. To prevent the table from being drawn in or the cutter from climbing on the work, some means for holding the table back, not allowing the lost motion to come into play, must be provided such as a weight which will keep the table against the pushing side of the feed nut. When fed against the cutter the table has sufficient weight in itself.

The preceding statement applies more generally to the horizontal feeds. When feeding up or down, the weight of the knee and table is sufficient to allow the cutter to be fed in either direction unless the cut is very heavy.

When the cutter is driven by the friction between the faces of the collars on the arbor, care must be taken that it is placed on the arbor in the correct way. If the nut which tightens the collar and cutter

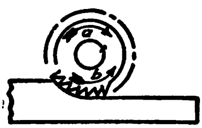



Fig. 120.—Placing of Cutter.

is left-handed, then the force which tends to rotate the cutter will tend to tighten this nut. Referring to Figure 120, if the cutter is revolved in the direction of the arrow, a, and force enough is applied to the cutter teeth to make the cutter slip or rotate, it will tend to turn the collars and the nut in the direction of the arrow, b, and, as the nut is left-handed in this case, it will consequently be tightened, not loosened as would be the case if it were right-handed.

When very heavy duty is required of the cutter, a key is generally provided which makes it unnecessary to take the precaution of putting the cutter on in any particular way.

**Milling and Spacing Grooves.**—To illustrate the convenience of the dividing head and the graduated discs on the feeds of the milling machine, a description of milling and spacing the grooves in the piece shown at a in Figure 121 is here given. Here a series of grooves are to be milled in the piece as shown in the drawing.

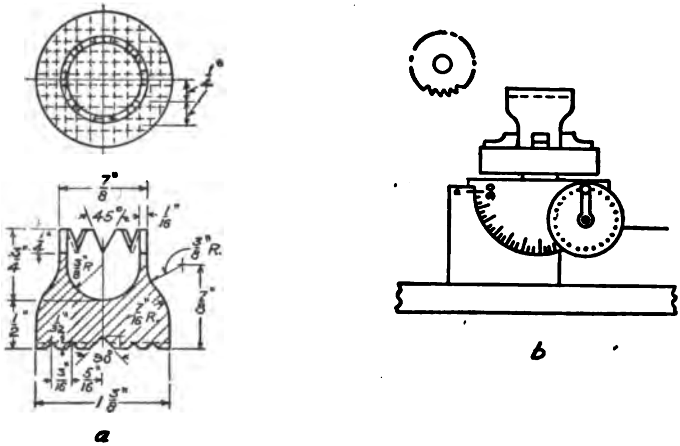



Fig. 121.—Exercise.

The diving head is swung around until the spindle is in a vertical position. as shown at b, and the piece is clamped in a chuck. A 90° angle cutter is placed on the arbor. With the cross feed the piece is fed in or out until the cutter is about in the center of the piece (it is better if the piece is a little too far out). A cut of not the full depth is taken across the piece where the deep central groove is to be. After this cut has been taken the piece is revolved 180° by means of the index crank. Twenty turns of the crank will do this. The cutter is run through the groove again and, if it is not quite in the center of the groove already cut, this can plainly be seen; the amount it is out can be corrected by moving the cross feed in one-half this amount. The piece will now be centered and all the lost motion of the cross feed will be taken up in the *in* direction of its motion. This is important as will be seen later. The cross feed disc can now be set at zero.

The second step will be to get the proper depth for the central groove which is 1/8 of an inch. This can be done by rotating the piece so that the cutter will pass, not through the groove, but at an angle to it. The knee must first be lowered until the cutter does not touch the piece. With the cutter rotating bring the knee up until the cutter lightly touches the piece. The graduated disc on the up-and-down feed can now be set to zero and the piece can be run out from under the cutter by the longitudinal feed. The disc having been set at zero, the knee can be raised 125 thousandths or 1/8 of an inch, the spindle of the dividing head can be rotated until the original central cut is in its proper position, and the first or deep cut can be run through the proper depth.

The third step will be to run the cross feed in 5/16 of an inch, the amount the drawing calls for. The in-and-out feed disc having been set at zero, this amount can be measured by running the cross feed in the required number of thousandths or .3125. The knee must now be dropped to zero again and then raised 1/32 of an inch which is the depth of the grooves on either side of the central groove. This groove can now be cut and, after this is done and the cutter is returned to the starting point, the spindle of the dividing head can be rotated 180° and the groove on the other side can be cut at the same depth and distance from the center as the first one was.

The fourth step will be to run the cross feed in 3/16 of an inch for the next groove. As the first groove from the center was 5/16 of an inch and as this one is 3/16 from it, the distance from the center groove to this one will be 5/16 plus 3/16 or ½ inch. Therefore, the cross feed must now be run in until the disc reads 500 thousandths of an inch from the starting point. The two outer grooves can now be cut in the same way as the first two were.

The piece must now be rotated 90°, or ten turns of the index crank. The cross feed must now be brought back to zero, care being taken that it is brought out a little beyond zero and is then fed in as in the first setting of the central groove. If fed *in* to zero, all the lost motion will be taken up in the same direction. This is why it was important that it should be done in the *in* direction in the first setting.

The five grooves can now be cut in the same manner as the first five were. All these grooves have been spaced as to depth and distance from each other without the use of a rule or gauge of any kind except those provided on the index head and the feeds of the machine.

**Cutting Speeds.**—The approximate cutting speed for high-carbon cutters on steel is from 30 to 40 feet per minute and on cast iron is from 40 to 60 feet per minute; on brass a speed of 80 to 100 feet per minute can be used without injuring the cutter. With high-speed steel these speeds may be doubled.

Not all the teeth of the milling cutters are cutting at one time, thus allowing some teeth a little time to cool off before coming into action again. When a tool is cutting on the lathe, it is in action all the time and will therefore get hotter as there is no time allowed for it to radiate any heat.

**Depth of Cut.**—The depth of the cut is dependent

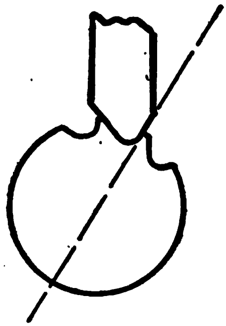


Fig. 122.—Setting of Reamer Cutter.

upon the strength of the piece being cut to resist the stress applied and also upon the hardness of the material being cut. Where cast iron is being machined with the sand still on the casting, the speed will probably have to be diminished, owing to the action of the sand on the cutter.

**Fluting Reamers and Taps.**—For fluting reamers and taps, specially formed cutters are provided. The face of the cutter that forms the cutting edge of the tap or reamer should be on a radial line with the blank being grooved. This is shown in Figure 122. To avoid chattering, the teeth of reamers are usually staggered; that is, they are not equally spaced.

**Helix Milling.**—Helices, sometimes incorrectly called spirals, can be cut on the universal milling machine and on the plane when a special head is provided whereby the cutter can be swung to the helix

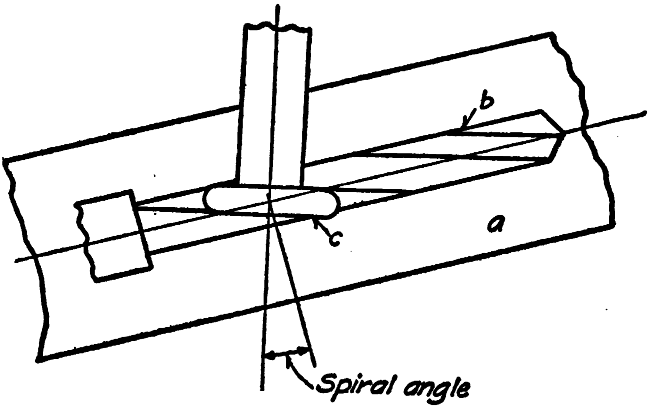



Fig. 123.—Helix Milling.

angle. With the universal machine the table is swung to the helix angle. An example of helix milling is shown in Figure 123. Here the grooves of a twist drill are being milled. The table has been swung around to the angle corresponding to the helix angle of the groove; b is the drill being grooved and c is the cutter. The view is looking down from the top.

**Bevel Gear Milling.**—Figure 124 shows the method employed in holding and cutting a bevel gear on the milling machine. The dividing head must be swung to the cutting angle of the gear. The gear is held on

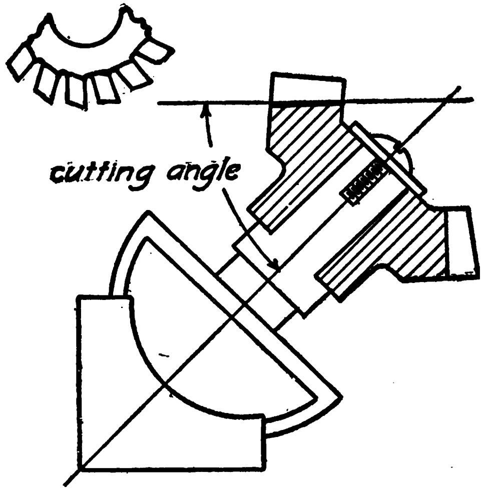



Fig. 124.—Bevel Gear Milling.

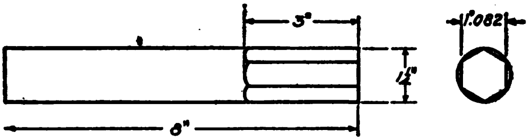
an expanding mandrel, which is held in the dividing head spindle.

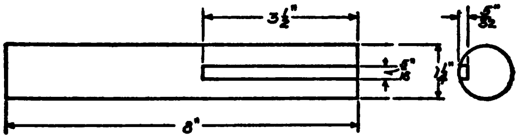
## QUESTIONS ON CHAPTER XII

1. Why must the tail of the dog be held rigid when driving a piece between the centers on the milling machine?
2. Why is a side mill better than an end mill for cutting keyways on a milling machine?
3. Why is it better to have the work lying flat on the table of the milling machine and use a vertical attachment?

4. Explain two methods of centering a cutter when the center must be in a vertical plane passing through the spindle of the dividing head.
5. Why is it necessary to feed the cutter in the proper direction?
6. Define the terms *feeding against the cutter* and *feeding with the cutter.*
7. Why should the cutter be placed on the arbor in different positions for a right and a left hand clamping nut?
8. How is a cutter kept from rotating in heavy duty?
9. Explain how a piece held in the chuck which is to have a groove through its center is centered in relation to the spindle of the dividing head.
10. How is the depth of a cut gauged?
11. What is the approximate cutting speed for steel, cast iron, and brass with high-carbon steel cutters?
12. What governs the depth of a cut?
13. Why are reamer teeth staggered?
14. What special feature must a milling machine have for cutting a helix?
15. Why is it important to have milling cutters sharp?
16. How are bevel gears held when cut in the milling machine?

## EXERCISES FOR PRACTICE.

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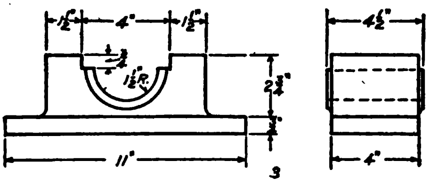


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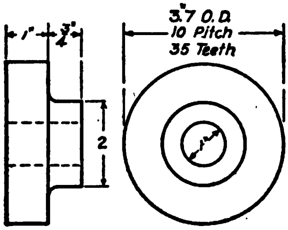


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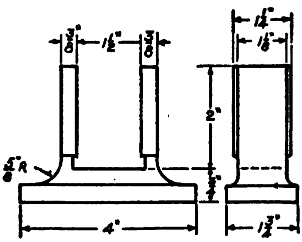


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# CHAPTER XIII

## THE AUTOMOBILE

**Fuel.**—The automobile or motor car uses for its fuel three things, namely gasoline, electricity, and kerosene.

*Gasoline.*—The gasoline fuel is the more popular as a large quantity of it can be carried on the car and it is an easy matter to have stations to supply the users of automobiles on the road.

*Electricity.*—The electric car has to carry in storage batteries enough electricity to run the car until it returns home or is able to get to a place where the batteries can be recharged. This must be done by machinery, and stations for recharging them along the road would have to be very numerous. About the longest run an electric car can make, with the batteries charged, is 40 miles; while, with a 20-gallon tank of gasoline, a medium weight gasoline car can run from 150 to 200 miles.

*Kerosene.*—The steam car, using kerosene, can carry as much fuel as the gasoline car. But, as yet the steam car has not been developed to a point where it is as efficient as the gasoline; at least not in public opinion, although it might be thought as efficient by those who are working on its development.

**Parts.**—The first great division of an automobile is the body and the chassis or running gear. The body is really quite separate from the car and as it is more of a shelter for the occupants than a piece of machinery, its construction will be omitted.

The word chassis has been adopted into the English language and means the frame springs, wheels, engine, transmission differential, and all that goes to make up the running gear. The mechanism proper, including the running gear and all that goes to propel and control it, is designated as the chassis.

**Chassis.**—The principal part of the chassis is the power plant which may be a gasoline engine, an electric motor, or a steam engine. In some kinds of gasoline cars the transmission is included in the power plant which is then known as a unit power plant; in others it is a separate piece of mechanism and is secured either to the frame, back of the clutch, or on the rear axle. The latter method is not, however, considered good.

The front axle assembly consists of the axle spindles connecting rod, and the necessary bolts and ball bearings to complete the assembly.

The rear axle assembly consists of the axle, the differential, the axle shafts, brake, brake shoes, etc.

The transmission consists of a case which carries the necessary gears and shafts for the different speeds and the reversing of the car.

The frame assembly is generally built of structural steel and has fastened to it the springs and braces necessary to make a substantial frame for carrying all the parts which with it comprise the complete chassis or running gear.

**Gasoline Engines.**—There are two types of engines; namely, four cycle and two cycle. As the four cycle is more generally used, its construction will be considered.

**Cycle.**—The meaning of the word cycle, when applied to a gasoline engine, is a succession of events. These events are certain things that happen during the two down and the two up movements of the piston.

*First, "Suction".*—The piston is at the top of the cylinder and passes to the bottom. In doing so, it sucks in a charge of gas and air, thus completing the first event.

*Second, "Compression".*—The piston returns to the top and at this time "compresses" the charge received in the previous movement, when the second event is completed.

*Third, Explosion.*—The compressed charge is now ignited and, by the force of the explosion, the piston is returned to the bottom of the cylinder, when the third event is completed.

*Fourth, Exhaust.*—The piston returns to the top of the cylinder and at the same time expels all the burnt gas, thus completing the fourth event, after which the piston is ready to repeat the cycle of events.

The gasoline is carried in a tank either under one of the seats in the car or at the back end on the frame.

Gasoline and air, combined into a vapor or mixture and then ignited, make a powerful explosion when in the proper proportions, which are about one part of gasoline to twelve or fourteen parts of air. This proportion will vary according to the quality of the gasoline, the conditions of the atmosphere, and the speed at which the engine is running.

**Carburetor.**—To obtain this vapor or mixture, a device called a carburetor is used, the construction of which is shown in Figure 125. The parts are numbered and a list of these with the names of the parts is given below:

1. Tank.
2. Carburetor bowl.
3. Inlet needle valve.
4. Cork float.
5. Needle valve to regulate the quantity of gas.
6. Air gate-valve.
7. Throttle gate-valve.
8. Baffle plate.
9. Intake pipe.

*Process.*—The gasoline flows from the tank, 1, into the carburetor bowl, 2, through the needle valve, 3. When the gasoline in the bowl reaches a certain height,

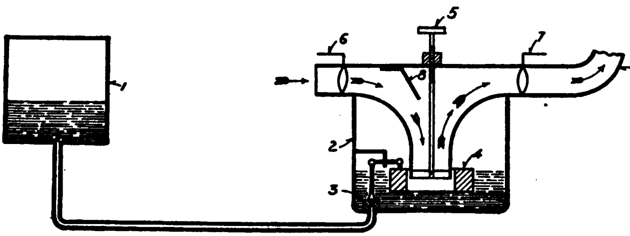



Fig. 125.—Carburetor.

the valve, 3, is closed by the cork float, 4. As the gasoline in the bowl is lowered in consequence of its being vaporized and taken to the engine, the cork float lowers and lifts the needle valve, 3, from its seat, allowing the gasoline to flow from the tank again until the proper level in the bowl is restored. In this way, a constant level of gasoline is maintained in the carburetor bowl.

*Control of Mixture.*—The quantity of gas entering the mixture is governed by the needle valve, 5, and the quantity of air is governed by the air gate valve, 6. The volume of gas and air mixture entering the intake pipe, 9, to the cylinders is controlled by the throttle gate valve, 7. The baffle plate, 8, is to prevent the air from rushing across into the intake pipe, 9, before it is mixed with the vapor.

*Mixtures.*—"Lean" mixture and "rich" mixture are expressions applied to certain air and gas mixtures. A lean mixture contains too much air and not enough gasoline. A rich mixture is the reverse, having too much gasoline and not enough air. A rich mixture will tend to overheat the cylinders and is also wasteful of the fuel, at the same time creating soot which covers the valves, cylinders, and piston.

*Proper Mixture.*—Back firing through the carburetor is often caused by a lean mixture. The mixture should be as lean as possible, but not so lean that it will sacrifice any of the power of the engine. If the exhaust smoke is heavy and black with a disagreeable smell, the mixture is too rich. When the mixture is proper there is very little smoke or odor.

**Ignition.**—To obtain an explosion of gasoline and air mixed together, the mixture must be ignited. The best way to do this is with an electric spark. A hot tube will do it, but is not so convenient as the electric spark.

*Magneto.*—Batteries in connection with an induction coil will give the necessary spark but, as the batteries wear out and have to be renewed, the magneto is a more satisfactory way of generating the current. The induction coil transforms the current to a higher pressure, thus giving a better spark.

*Commutator.*—This spark must be delivered at the proper time and to do this, what is called a commutator is employed. The commutator makes and breaks and

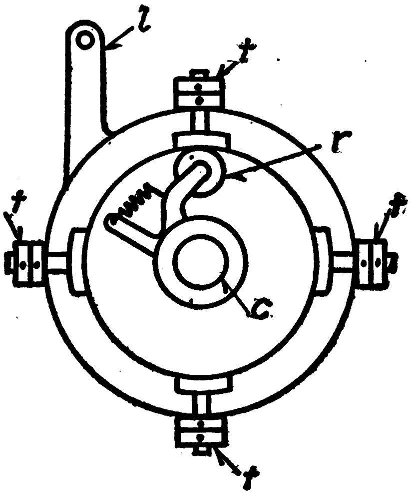



Fig. 126.—Commutator.

times the current. The spark plug delivers the spark to the mixture which has been drawn into the cylinder.

A commutator is shown in Figure 126, which has a spring roller contact, r, rotated by the cam shaft, c. The four contact points are at t, t, t, t, one each of these going to the different cylinders. L is a lever for advancing or retarding the spark by rotating the frame carrying the contact points, t, t, t, t.

**Engine.**—In Figure 127 is shown a vertical section of an automobile engine. c is the cylinder, p the piston, r the connecting rod, s the crank shaft, w the flywheel, and f the crank case. There are four cylinders, four pistons, and four connecting rods, one crank shaft, one crank case, and one flywheel.

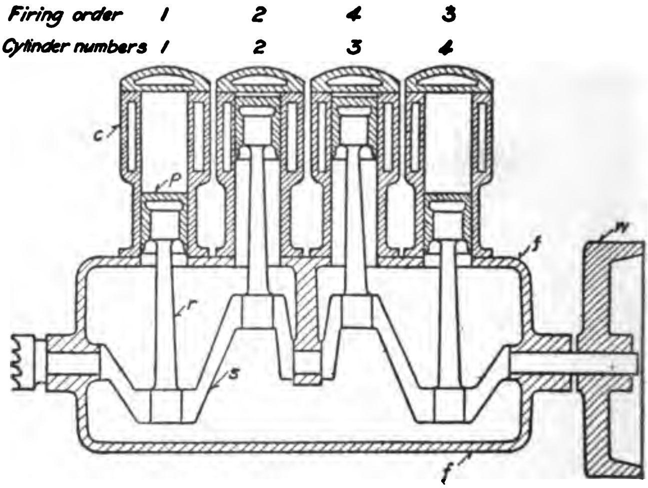



Fig. 127.—Automobile Engine.

In four cylinder engines, the crank shafts are generally made as shown, the two central cranks at one position and the two end ones 180° from this position. With this arrangement there are always two pistons moving in one direction while the other two are moving in the opposite direction. This balanced or uniform movement tends to prevent shock. On the end of the crank shaft opposite the flywheel is placed a ratchet clutch for starting or cranking the engine. The cam shaft has been omitted in this sketch.

**Types of Cylinders.**—There are two types of cylinders known as T-type head and L-type head. The T-type necessitates two cam shafts, one on either side of the engine; whereas with the L-type, only one cam shaft is required although it must have two sets of

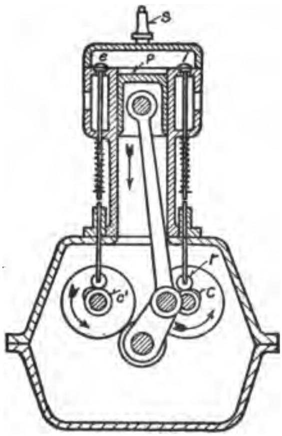



Fig. 128.—T-Head Engine.

cams, one for the intake and one for the exhaust valves. The L-type requires fewer moving parts and consequently should be better.

**T-Head Gasoline Engine.**—In Figure 128 is shown an end view of a T-head gasoline engine. The piston is in the act of moving down and drawing in a charge of gas through the intake valve, i. This valve is opened by the cam, c, on the right of the sketch. This cam is so formed that it opens the valve and keeps it open for the required time and then closes it. By the time that the piston has reached the bottom of the cylinder, the cam has closed valve, i, and the piston now returns to the top of the cylinder. As both valves, i, and e, are closed and the piston has packing rings, all leakage of the charge just received is prevented and the piston compresses the charge until it comes almost to the top. The compressed charge is now ignited by the spark from the spark plug, s. The force of the explosion sends the piston again to the bottom of the cylinder whence it returns and at this time expels the burnt gas, remaining from the explosion, through the valve, e, which opens on the instant the piston starts to return to the top. The cam c on the left of the sketch opens the valve at the proper time.

**Explosions.**—In the preceding description it is readily seen how the piston is moved in the third event; namely, the explosion. But the other movements are not so evident as this one and can be explained as follows:

In Figure 127 there are four cylinders, each one of which has a piston, p, and a connecting rod, r. Each connecting rod is attached to the crank shaft, s. As an explosion occurs every fourth event and, as there are four cylinders, there are consequently four explosions during the cycle of the engine.

*First Explosion.*—When No. 1 is exploding, it is pushing Nos. 2 and 3 to the top, No. 2 compressing its charge and No. 3 exhausting; while No. 4, which is going down with No. 1, is receiving its charge.

*Second Explosion.*—Now No. 2 explodes and goes to the bottom, taking No. 3 to the bottom also and Nos. 1 and 4 to the top. As No. 4 goes to the top it compresses its charge, No. 1 exhausts, and No. 3 takes in a charge.

*Third Explosion.*—No. 4 has its charge compressed, explodes, and goes to the bottom, taking down No. 1, which is receiving a charge, and taking up Nos. 2 and 3, No. 2 exhausting and No. 3 compressing.

*Fourth Explosion.*—The fourth explosion is in No. 3, which takes down with it No. 2, receiving a charge, and takes up No. 1 and No. 4, No. 4 exhausting and No. 1 compressing.

No. 1 is now ready to explode again and the same cycle is repeated again and again as long as the fuel is fed to the engine.

**Firing Order.**—The order of the explosions as regards the numbers of the cylinders is spoken of as the firing order. In the engine just described, the order is No. 1, No. 2, No. 4, No. 3.

It is not possible to have it No. 1, No. 2, No. 3, No. 4, because, when No. 2 explodes, it takes down No. 3, which is either taking in gas or exploding; and, as an explosion can only happen directly after a compression, there is left only No. 4 to have the next explosion as its compression has just been completed. Of course, No. 1 could not explode twice in succession, it having just exploded before No. 2.

**Complete Power Plant.**—With the gasoline and air as fuel, the carburetor for combining them, and the ignition system for igniting the combination, and with all these in conjunction with the motor, a power plant is provided for propelling the automobile.

**Connection.**—It now remains to connect this power plant with the rear wheels of the car. This is generally done by means of a clutch for engaging and disengaging the power plant, a transmission for varying the speed and for reverse, and a differential which permits the rear wheels to revolve at different speeds while at the same time each receives an equal division

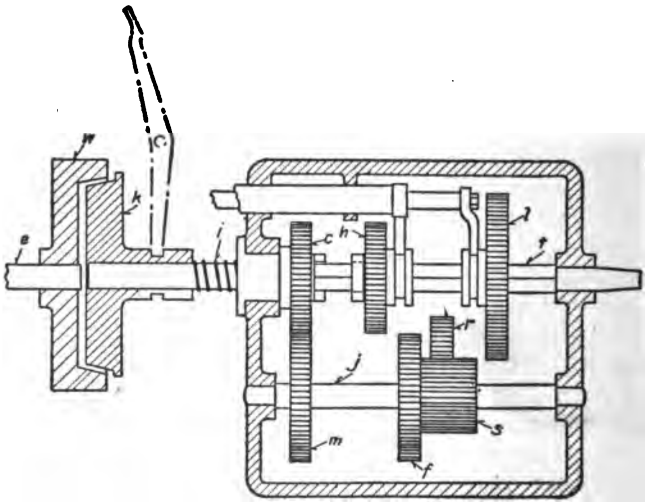


Fig. 129.—Transmission.

of the power. When turning a corner, it is necessary that the outer wheel should revolve faster than the inner. If the differential were not there, both wheels would have to revolve at the same speed and the inner wheel would have to slip. This slipping would be dctrimental to the tires.

**Transmission.**—A form of transmission is shown in Figure 129. The flywheel, w, is keyed to the crank shaft, e, of the engine. The clutch, k, slides on the shaft, i, and is keyed to it with a sliding key. The spring shown back of this clutch pushes it into the tapered part of the flywheel, w. The lever, p, is controlled by the driver's foot. When it is released the clutch is free to engage with the flywheel. The spring holds the clutch in all the time the car is running. When the transmission is in neutral the clutch can be in without running the car. When the clutch, k, is set in its seat and the engine is revolving, shaft, i, revolves also. To shaft, i, is keyed gear wheel, c, which meshes into wheel, m. Therefore, when the clutch is in, the shafts i and j, and the wheels, m, f, and s, which are keyed to it, revolve together.

*Varying Speeds.*—The transmission shaft, t, is still at rest. If the wheel, l, is slid along it into mesh with gear, s, it will be in low gear. If the gear, l, is slid out of mesh and gear, h, is slid into mesh with gear, f, the transmission shaft will be in middle gear. Now, if gear, h, is slid out of mesh and pushed on until the clutch on the end of shaft, i, and the hub of gear, h, are engaged, the shaft, t, will be running on high and there will be no gear action between the engine and the differential but will be in what is called direct drive.

*Reverse.*—To reverse the direction of rotation of shaft, t, gear, h, is slid along shaft, t, until it engages with gear, r, which is an idler meshing with gear, s. When the gears are as shown in the sketch, the transmission is in neutral; that is, the car cannot move although the engine and shafts, i and j, are revolving. These gears and shafts are enclosed in a gear case partly filled with grease to insure perfect lubrication.

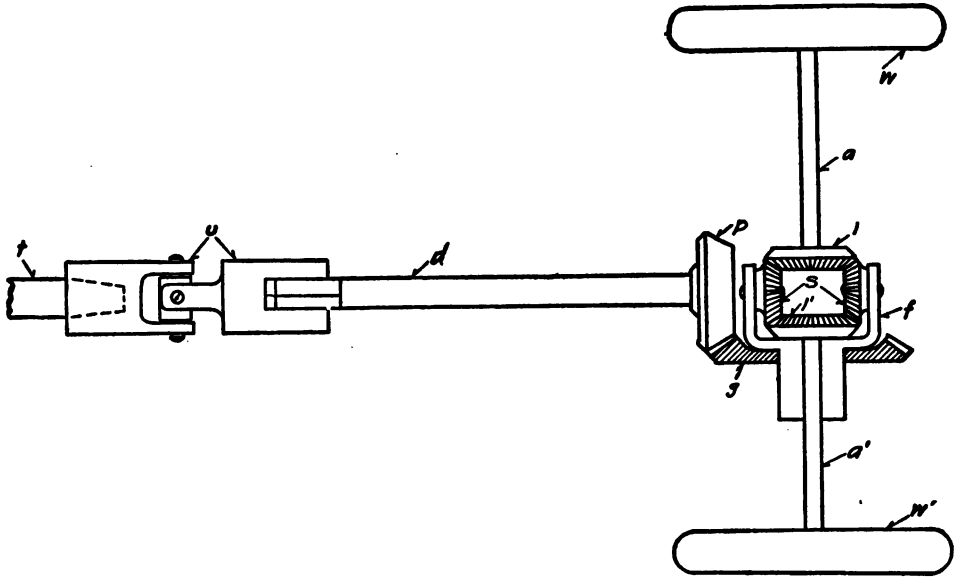



Fig. 130.—Drive Shaft and Differential.

**Connection with Rear Axle.**—It is now necessary to connect the transmission with the rear axle in order to drive the rear wheels and propel the car. This is done through the universal joint, drive shaft, and differential.

*Universal Joint and Drive Shaft.*—In Figure 130 is shown a sketch of these parts. T is the transmission shaft, which is also shown in Figure 129. To it is attached the universal joint, u. One piece of this joint has a square hole in which the drive shaft, d, fits. Some end motion is allowed in this to compensate for the up-and-down motion of the rear axle. The flexibility of the universal joint allows the drive shaft to run at the angle required by the relative position of the transmission and differential and permits the twisting and turning of the axle as the wheels travel over surfaces that are not even.

*Differential.*—To the end of the drive shaft is secured the drive shaft pinion, p, which meshes into the large bevel gear that is keyed to the fork, f. This fork carries the differential pinions, s (only two are shown here, sometimes 3 or 4 are used), which mesh into the differential gears, 1, 1′. These gears are secured to the axle shafts, a and a′, which drive the wheels, w, w′.

**Action of Differential.**—The action of the differential is as follows:

The large gear, g, is rotating in one direction all the time and is turning with it the fork, f. If the pressure on both the rear wheels of the machine is the same, the pinions, s, do not revolve on their axis but act as clutches driving both axle shafts at the same speed. When rounding a corner one of the wheels of

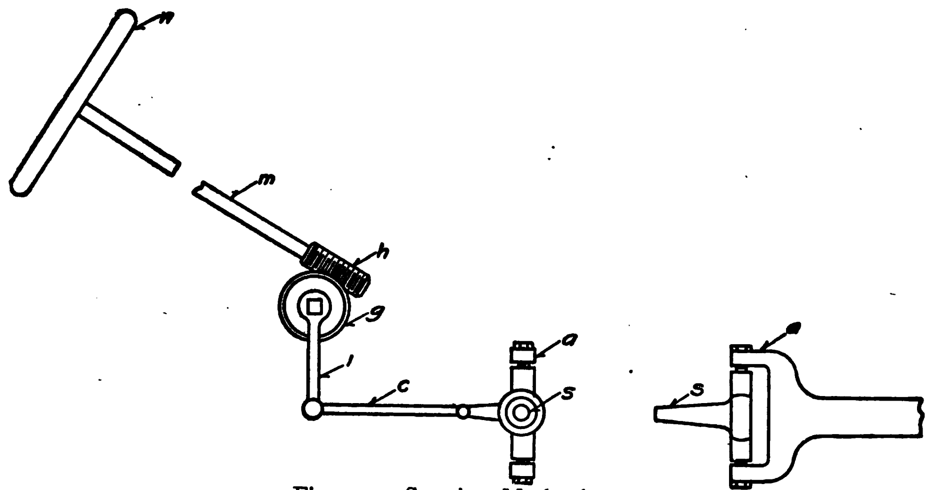


Fig. 131.—Steering Mechanism.

the car (the inner one) does not revolve so fast as the outer. If the shafts, a, a′, were connected rigidly, the inner one would have to slip when the outer one is compelled to go faster owing to the greater radius of its path. But with the differential, if one of the wheels, for example, w′, were held from turning, gear, l′, would remain at rest and the fork with the pinions, s, revolving would transmit motion to gear, l, partly by tooth action and also by the same action it receives when the pressure is equal on both wheels, or by what might be called a combination of clutch and gear action.

**Steering Mechanism.**—The running gear is incomplete without the steering mechanism. This is shown in Figure 131. w is the steering wheel which is keyed to the mast, m. On the other end of the mast is keyed the worm, h, which engages into the worm gear, g. The lever, l, is secured to the worm wheel, g, by a square projection. The spindle, s, is rotated in the fork of the axle, a, through the rod, c, and lever, l. In figure 132 are shown a diagram of the chassis and the location of the parts previously described.

## THE STEAM CAR

**Advantages.**—The steam motor has some advantages over the gasoline; namely, speed variations can be obtained without the shifting of gears, the speed being regulated by the throttle. Cranking, which in the gasoline car is done away with by the use of the self starter, is not needed on the steam car. The steam engine is more quiet-running than the exploding motors and it is claimed that it climbs hills better.

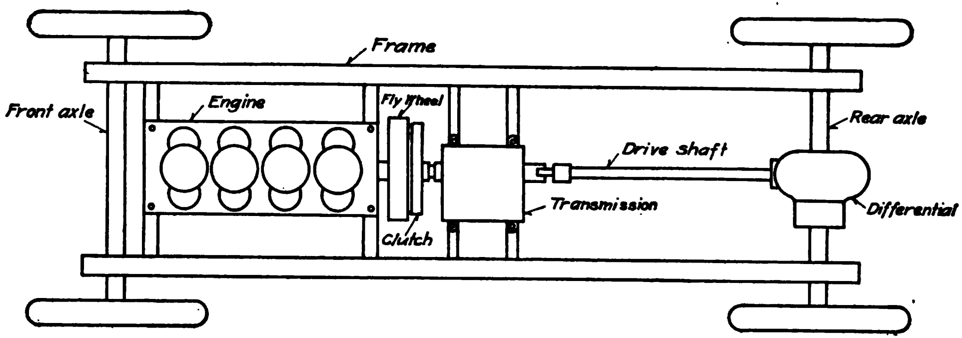



Fig. 132.—Chassis.

*Fewer Parts.*—In the steam auto the carburetor and ignition are eliminated; the clutch and transmission are unnecessary and are, therefore, omitted. The fuel can be either gasoline or kerosene. The latter at the present time is cheaper. There are fewer moving parts, which is another decided advantage.

*Double Action.*—There is a material difference between the steam engine used on automobiles and the gasoline engine. The steam engine is double-acting while the gasoline is single. In the steam engine there is always a pressure on one side or the other of the piston, which is always available for work.

*Constant Pressure.*—As long as there is a pressure in the boiler the steam engine can never be stalled because of this constant pressure. Steam engines are generally made with two cylinders, with the cranks set at 90° to each other. Thus, there is always one crank which is in a position to move the engine. The two-cylinder simple engine is used on some kinds of cars and the two-cylinder compound engine on others. In the two-cylinder simple engine each cylinder receives its steam supply from the boiler independent of the other.

*Only Two Cylinders.*—The number of cylinders in the gasoline engine have been increased from two to four, six, eight; and now twelve cylinders in some instances are being employed. This has been done to give a smooth continuous torque to the crank shaft, while two cylinders in the steam engine will secure this, it is claimed, and with fewer moving parts.

**Valve Gears.**—There are two types of valve gears in use on steam automobile engines, the Stephenson link motion and the Joy valve gear. The Stephenson link motion is the old familiar link motion used on locomotives, which consists of a link and a forward and reverse eccentric. The Joy valve gear is a system of levers and an adjustable guide which receive their motion from the connecting rod of the engine.

**Disadvantages.**—Probably the fact that any boiler is more or less dangerous and liable to explode deterred the adoption of the steam engine. Then, again, the heat from a steam boiler might be another objection, although it is claimed that there is no more heat from a steam boiler with the present means at hand for insulating it than there is from a gasoline engine.

**Boilers.**—The first boilers were of the flash type; that is, the steam was made instantly at the time it was required: but the steam which supplies the present engine is stored in a generating plant under the hood.

## QUESTIONS ON CHAPTER XIII

1. What is the first great division of an automobile?
2. What parts compose the chassis?
3. What is a unit power plant?
4. What is the purpose of the transmission?
5. Is the two cycle or the four cycle engine most generally used on automobiles?
6. What is the meaning of the word cycle when applied to a gas engine?
7. Give the names of the events in order.
8. What is the purpose of the carburetor?
9. Why must the explosive mixture be ignited?
10. What is the best method of igniting the charge?
11. What is the purpose of the induction coil?
12. What is the function of the commutator?
13. How are the cranks of a four cylinder engine placed relatively to each other?

14. Why are they so placed?
15. What two types of cylinders, as regards their heads, are used on automobiles?
16. What conditions are necessary for compressing the charge?
17. State what is happening in the other three cylinders when No. 1 is exploding?
18. What is meant by the expression "firing order"?
19. Why must the drive shaft have some end motion in the universal joint?
20. What is the purpose of the universal joint?
21. Why is the differential employed on the rear axle?
22. Explain the action of the differential.
23. Name some of the advantages of the steam engine over the gasoline.
24. What material difference is there between the steam and the gasoline engine?
25. What two principal valve gears are used on the steam engine?
26. Why is the number of cylinders increased in the gas engine and why are only two used in the steam engine?

# APPENDIX

## TABLE OF DECIMAL EQUIVALENTS OF 8ths, 16ths, 32ds, and 64ths OF AN INCH

### 8ths.

| | |
|---|---|
| 1/8 | .125 |
| 1/4 | .250 |
| 3/8 | .375 |
| 1/2 | .500 |
| 5/8 | .625 |
| 3/4 | .750 |
| 7/8 | .875 |

### 16ths.

| | |
|---|---|
| 1/16 | .0625 |
| 3/16 | .1875 |
| 5/16 | .3125 |
| 7/16 | .4375 |
| 9/16 | .5625 |
| 11/16 | .6875 |
| 13/16 | .8125 |
| 15/16 | .9375 |

### 32ds.

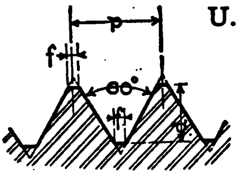
| | |
|---|---|
| 1/32 | .03125 |
| 3/32 | .09375 |
| 5/32 | .15625 |
| 7/32 | .21875 |
| 9/32 | .28125 |
| 11/32 | .34375 |
| 13/32 | .40625 |
| 15/32 | .46875 |
| 17/32 | .53125 |
| 19/32 | .59375 |
| 21/32 | .65625 |
| 23/32 | .71875 |
| 25/32 | .78125 |
| 27/32 | .84375 |
| 29/32 | .90625 |
| 31/32 | .96875 |

### 64ths.

| | |
|---|---|
| 1/64 | .015625 |
| 3/64 | .046875 |
| 5/64 | .078125 |
| 7/64 | .109375 |
| 9/64 | .140625 |
| 11/64 | .171875 |
| 13/64 | .203125 |
| 15/64 | .234375 |
| 17/64 | .265625 |
| 19/64 | .296875 |
| 21/64 | .328125 |
| 23/64 | .359375 |
| 25/64 | .390625 |
| 27/64 | .421875 |
| 29/64 | .453125 |
| 31/64 | .484375 |
| 33/64 | .515625 |
| 35/64 | .546875 |
| 37/64 | .578125 |
| 39/64 | .609375 |
| 41/64 | .640625 |
| 43/64 | .671875 |
| 45/64 | .703125 |
| 47/64 | .734375 |
| 49/64 | .765625 |
| 51/64 | .796875 |
| 53/64 | .828125 |
| 55/64 | .859375 |
| 57/64 | .890625 |
| 59/64 | .921875 |
| 61/64 | .953125 |
| 63/64 | .984375 |

## TABLE OF DECIMAL EQUIVALENTS

| Thirds, Sixths, Twelfths and Twenty-fourths | | Sevenths, Fourteenths and Twenty-eighths | |
|---|---|---|---|
| 1/24 | .041666 | 1/28 | .035714 |
| 1/12 | .083333 | 1/14 | .071429 |
| 3/24 | .125 | 3/28 | .107143 |
| 1-6 | .166666 | 1-7 | .142857 |
| 5/24 | .208333 | 5/28 | .178571 |
| 3/12 | .250 | 3/14 | .214286 |
| 7/24 | .291666 | 7/28 | .250 |
| 1-3 | .333333 | 2-7 | .285714 |
| 9/24 | .375 | 9/28 | .321429 |
| 5/12 | .416666 | 5/14 | .357143 |
| 11/24 | .458333 | 11/28 | .392857 |
| 3-6 | .500 | 3-7 | .428571 |
| 13/24 | .541666 | 13/28 | .464286 |
| 7/12 | .583333 | 7/14 | .500 |
| 15/24 | .625 | 15/28 | .535714 |
| 2-3 | .666666 | 4-7 | .571429 |
| 17/24 | .708333 | 17/28 | .607143 |
| 9/12 | .750 | 9/14 | .642857 |
| 19/24 | .791666 | 19/28 | .678571 |
| 5-6 | .833333 | 5-7 | .714286 |
| 21/24 | .875 | 21/28 | .750 |
| 11/12 | .916666 | 11/14 | .785714 |
| 23/24 | .958333 | 23/28 | .821429 |
| 1 | 1.000 | 6-7 | .857143 |
| | | 25/28 | .892857 |
| | | 13/14 | .928571 |
| | | 27/28 | .964286 |
| | | 1 | 1.000 |




# U. S. STANDARD SCREW THREADS

$p = \text{pitch} = \frac{\quad}{\text{No. threads per inch}}$

$d = \text{depth} = p \times .6495$

$f = \text{flat} = \frac{p}{8}$

| Diameter of Screw | Threads per Inch | Diam. at Root of Thread | Width of Flat |
|---|---|---|---|
| ¼ | 20 | .185 | .0063 |
| 5/16 | 18 | .2403 | .0069 |
| ⅜ | 16 | .2936 | .0078 |
| 7/16 | 14 | .3447 | .0089 |
| ½ | 13 | .4001 | .0096 |
| 9/16 | 12 | .4542 | .0104 |
| ⅝ | 11 | .5069 | .0114 |
| ¾ | 10 | .6201 | .0125 |
| ⅞ | 9 | .7307 | .0139 |
| 1 | 8 | .8376 | .0156 |
| 1⅛ | 7 | .9394 | .0179 |
| 1¼ | 7 | 1.0644 | .0179 |
| 1⅜ | 6 | 1.1585 | .0208 |
| 1½ | 6 | 1.2835 | .0208 |
| 1⅝ | 5½ | 1.3888 | .0227 |
| 1¾ | 5 | 1.4902 | .0250 |
| 1⅞ | 5 | 1.6152 | .0250 |
| 2 | 4½ | 1.7113 | .0278 |
| 2¼ | 4½ | 1.9613 | .0278 |
| 2½ | 4 | 2.1752 | .0313 |
| 2¾ | 4 | 2.4252 | .0313 |
| 3 | 3½ | 2.6288 | .0357 |
| 3¼ | 3½ | 2.8788 | .0357 |
| 3½ | 3¼ | 3.1003 | .0385 |
| 3¾ | 3 | 3.3170 | .0417 |
| 4 | 3 | 3.5670 | .0417 |
| 4¼ | 2⅞ | 3.7982 | .0435 |
| 4½ | 2¾ | 4.0276 | .0455 |
| 4¾ | 2⅝ | 4.2551 | .0476 |
| 5 | 2½ | 4.4804 | .0500 |
| 5¼ | 2½ | 4.7304 | .0500 |
| 5½ | 2⅜ | 4.9530 | .0526 |
| 5¾ | 2⅜ | 5.2030 | .0526 |
| 6 | 2¼ | 5.4226 | .0556 |

# DOUBLE DEPTH OF THREADS

| Threads per In. | V Threads D D | U. S. Standard D D | Whit. Standard D D | Threads per In. | V Threads D D | U. S. Standard D D | Whit. Standard D D |
|---|---|---|---|---|---|---|---|
| 2 | .86650 | .64950 | .64000 | 28 | .06185 | .04639 | .04571 |
| 2¼ | .77022 | .57733 | .56888 | 30 | .05773 | .04330 | .04266 |
| 2⅜ | .72960 | .54694 | .53894 | 32 | .05412 | .04059 | .04000 |
| 2½ | .69320 | .51960 | .51200 | 34 | .05097 | .03820 | .03764 |
| 2⅝ | .66015 | .49485 | .48761 | 36 | .04811 | .03608 | .03555 |
| 2¾ | .63019 | .47236 | .46545 | 38 | .04560 | .03418 | .03368 |
| 2⅞ | .60278 | .45182 | .44521 | 40 | .04330 | .03247 | .03200 |
| 3 | .57733 | .43300 | .42666 | 42 | .04126 | .03093 | .03047 |
| 3¼ | .53323 | .39966 | .39384 | 44 | .03936 | .02952 | .03136 |
| 3½ | .49485 | .37114 | .36571 | 46 | .03767 | .02823 | .02782 |
| 4 | .43300 | .32475 | .32000 | 48 | .03608 | .02706 | .02666 |
| 4½ | .38488 | .28869 | .28444 | 50 | .03464 | .02598 | .02560 |
| 5 | .34660 | .25980 | .25600 | 52 | .03332 | .02498 | .02461 |
| 5½ | .31490 | .23618 | .23272 | 54 | .03209 | .02405 | .02370 |
| 6 | .28866 | .21650 | .21333 | 56 | .03093 | .02319 | .02285 |
| 7 | .24742 | .18557 | .18285 | 58 | .02987 | .02239 | .02206 |
| 8 | .21650 | .16237 | .16000 | 60 | .02887 | .02165 | .02133 |
| 9 | .19244 | .14433 | .14222 | 62 | .02795 | .02095 | .02064 |
| 10 | .17320 | .12990 | .12800 | 64 | .02706 | .02029 | .02000 |
| 11 | .15745 | .11809 | .11636 | 66 | 02625 | .01968 | .01939 |
| 11½ | .15069 | .11295 | .11121 | 68 | .02548 | .01910 | .01882 |
| 12 | .14433 | .10825 | .10666 | 70 | .02475 | .01855 | .01728 |
| 13 | .13323 | .09992 | .09846 | 72 | .02407 | .01804 | .01782 |
| 14 | .12357 | .09278 | .09142 | 74 | .02341 | .01752 | .01729 |
| 15 | .11555 | .08660 | .08533 | 76 | .02280 | .01714 | .01673 |
| 16 | .10825 | .08118 | .08000 | 78 | .02221 | .01665 | .01641 |
| 18 | .09622 | .07216 | .07111 | 80 | .02166 | .01623 | .01600 |
| 20 | .08660 | .06495 | .06400 | 82 | .02113 | .01584 | .01560 |
| 22 | .07872 | .05904 | .05818 | 84 | .02063 | .01546 | .01523 |
| 24 | .07216 | .05412 | .05333 | 86 | .02015 | .01510 | .01476 |
| 26 | .06661 | .04996 | .04923 | 88 | .01957 | .01476 | .01454 |
| 27 | .06418 | .04811 | .04740 | 90 | .01925 | .01443 | .01422 |

# DRILL LIST FOR MACHINE SCREW TAPS

| Size of Tap | Size of Drill | Size of Tap | Size of Drill |
|---|---|---|---|
| 1, 56 | 54 | 11, 28 | 20 |
| 1, 60 | 54 | 11, 30 | 19 |
| 1, 64 | 54 | 12, 20 | 22 |
| 1, 72 | 54 | 12, 22 | 20 |
| 1½, 56 | 53 | 12, 24 | 19 |
| 2, 48 | 50 | 12, 28 | 18 |
| 2, 56 | 49 | 13, 20 | 17 |
| 2, 64 | 48 | 13, 22 | 17 |
| 3, 40 | 47 | 13, 24 | 15 |
| 3, 48 | 45 | 14, 20 | 15 |
| 3, 56 | 44 | 14, 22 | 11 |
| 4, 32 | 45 | 14, 24 | 10 |
| 4, 36 | 44 | 15, 18 | 10 |
| 4, 40 | 43 | 15, 20 | 8 |
| 5, 30 | 41 | 15, 22 | 7 |
| 5, 32 | 40 | 15, 24 | 6 |
| 5, 36 | 39 | 16, 16 | 10 |
| 5, 40 | 38 | 16, 18 | 7 |
| 6, 30 | 36 | 16, 20 | 5 |
| 6, 32 | 35 | 18, 16 | 2 |
| 6, 36 | 34 | 18, 18 | 1 |
| 6, 40 | 33 | 18, 20 | A |
| 7, 28 | 33 | 20, 16 | C |
| 7, 30 | 32 | 20, 18 | E |
| 7, 32 | 31 | 20, 20 | F |
| 8, 24 | 31 | 22, 16 | H |
| 8, 30 | 30 | 22, 18 | J |
| 8, 32 | 29 | 24, 14 | L |
| 9, 24 | 30 | 24, 16 | M |
| 9, 28 | 28 | 24, 18 | N |
| 9, 30 | 28 | 26, 14 | O |
| 9, 32 | 26 | 26, 16 | P |
| 10, 24 | 27 | 28, 14 | R |
| 10, 30 | 24 | 28, 16 | S |
| 10, 32 | 23 | 30, 14 | U |
| 11, 24 | 22 | 30, 16 | V |

In most cases it is advisable to use drills one or even two sizes larger than above list.

# TAPERS AND ANGLES

| Taper Per Foot | Included < Deg. | Included < Min. | With Center Line / Deg. | With Center Line / Min. | Taper Per Inch | Taper Per Inch from Center Line |
|---|---|---|---|---|---|---|
| 1/8 | 0 | 36 | 0 | 18 | .010416 | .005203 |
| 3/16 | 0 | 54 | 0 | 27 | .015625 | .007812 |
| 1/4 | 1 | 12 | 0 | 36 | .020833 | .010416 |
| 5/16 | 1 | 30 | 0 | 45 | .026042 | .013021 |
| 3/8 | 1 | 47 | 0 | 53 | .031250 | .015625 |
| 7/16 | 2 | 05 | 1 | 02 | .036458 | .018229 |
| 1/2 | 2 | 23 | 1 | 11 | .041667 | .020833 |
| 9/16 | 2 | 42 | 1 | 21 | .046875 | .023438 |
| 7/8 | 3 | 00 | 1 | 30 | .052084 | .026042 |
| 11/16 | 3 | 18 | 1 | 39 | .057292 | .028646 |
| 3/4 | 3 | 25 | 1 | 47 | .062500 | .031250 |
| 13/16 | 3 | 52 | 1 | 56 | .067708 | .033854 |
| 7/8 | 4 | 12 | 2 | 06 | .072917 | .036456 |
| 15/16 | 4 | 28 | 2 | 14 | .078125 | .039063 |
| 1 | 4 | 45 | 2 | 23 | .083330 | .041667 |
| 1 1/4 | 5 | 58 | 2 | 59 | .104666 | .052084 |
| 1 1/2 | 7 | 08 | 3 | 34 | .125000 | .062500 |
| 1 3/4 | 8 | 20 | 4 | 10 | .145833 | .072917 |
| 2 | 9 | 32 | 4 | 46 | .166666 | .083332 |
| 2 1/2 | 11 | 54 | 5 | 57 | .208333 | .104166 |
| 3 | 14 | 16 | 7 | 08 | .250000 | .125000 |
| 3 1/2 | 16 | 36 | 8 | 18 | .291666 | .145833 |
| 4 | 18 | 54 | 9 | 27 | .333333 | .166666 |
| 4 1/2 | 21 | 40 | 10 | 50 | .375000 | .187500 |
| 5 | 24 | 04 | 12 | 02 | .416666 | .208333 |
| 6 | 28 | 06 | 14 | 03 | .500000 | .250000 |

## DIFFERENT STANDARDS FOR WIRE GAUGE IN USE IN THE UNITED STATES

Dimensions of Sizes in Decimal Parts of an Inch

| No. of Wire Gauge | American or Brown & Sharpe | Birmingham or Stubs' Wire | Washburn & Moen Mfg. Co., Worcester, Mass. | Trenton Iron Co., Trenton, N. J. | Stubs' Steel Wire | U. S. Standard for Plate | No. of Wire Gauge |
|---|---|---|---|---|---|---|---|
| 000000 | ....... | ..... | ..... | ..... | ..... | .46875 | 000000 |
| 00000 | ....... | ..... | ..... | .45 | ..... | .4375 | 00000 |
| 0000 | .46 | .454 | .3938 | .4 | ..... | .40625 | 0000 |
| 000 | .40964 | .425 | .3625 | .36 | ..... | .375 | 000 |
| 00 | .3648 | .38 | .3310 | .33 | ..... | .34375 | 00 |
| 0 | .32486 | .34 | .3065 | .305 | ..... | .3125 | 0 |
| 1 | .2893 | .3 | .2830 | .285 | .227 | .28125 | 1 |
| 2 | .25763 | .284 | .2625 | .265 | .219 | .265625 | 2 |
| 3 | .22942 | .259 | .2437 | .245 | .212 | .25 | 3 |
| 4 | .20431 | .238 | .2253 | .225 | .207 | .234375 | 4 |
| 5 | .18194 | .22 | .2070 | .205 | .204 | .21875 | 5 |
| 6 | .16202 | .203 | .1920 | .19 | .201 | .203125 | 6 |
| 7 | .14428 | .18 | .1770 | .175 | .199 | .1875 | 7 |
| 8 | .12849 | .165 | .1620 | .16 | .197 | .171875 | 8 |
| 9 | .11443 | .148 | .1483 | .145 | .194 | .15625 | 9 |
| 10 | .10189 | .134 | .1350 | .13 | .191 | .140625 | 10 |
| 11 | .090742 | .12 | .1205 | .1175 | .188 | .125 | 11 |
| 12 | .080808 | .109 | .1055 | .105 | .185 | .109375 | 12 |
| 13 | .071961 | .095 | .0915 | .0925 | .182 | .09375 | 13 |
| 14 | .064084 | .083 | .0800 | .08 | .180 | .078125 | 14 |
| 15 | .057068 | .072 | .0720 | .07 | .178 | .0703125 | 15 |
| 16 | .05082 | .065 | .0625 | .061 | .175 | .0625 | 16 |
| 17 | .045257 | .058 | .0540 | .0525 | .172 | .05625 | 17 |
| 18 | .040303 | .049 | .0475 | .045 | .168 | .05 | 18 |
| 19 | .03589 | .042 | .0410 | .04 | .164 | .04375 | 19 |
| 20 | .031961 | .035 | .0348 | .035 | .161 | .0375 | 20 |
| 21 | .028462 | .032 | .03175 | .031 | .157 | .034375 | 21 |
| 22 | .025347 | .028 | .0286 | .028 | .155 | .03125 | 22 |
| 23 | .022571 | .025 | .0258 | .025 | .153 | .028125 | 23 |
| 24 | .0201 | .022 | .0230 | .0225 | .151 | .025 | 24 |
| 25 | .0179 | .02 | .0204 | .02 | .148 | .021875 | 25 |
| 26 | .01594 | .018 | .0181 | .018 | .146 | .01875 | 26 |
| 27 | .014195 | .016 | .0173 | .017 | .143 | .0171875 | 27 |
| 28 | .012641 | .014 | .0162 | .016 | .139 | .015625 | 28 |
| 29 | .011257 | .013 | .0150 | .015 | .134 | .0140625 | 29 |
| 30 | .010025 | .012 | .0140 | .014 | .127 | .0125 | 30 |
| 31 | .008928 | .01 | .0132 | .013 | .120 | .0109375 | 31 |
| 32 | .00795 | .009 | .0128 | .012 | .115 | .01015625 | 32 |
| 33 | .00708 | .008 | .0118 | .011 | .112 | .009375 | 33 |
| 34 | .006304 | .007 | .0104 | .01 | .110 | .00859375 | 34 |
| 35 | .005614 | .005 | .0095 | .0095 | .108 | .0078125 | 35 |
| 36 | .005 | .004 | .0090 | .009 | .106 | .00703125 | 36 |
| 37 | .004453 | ..... | ..... | .0085 | .103 | .006640625 | 37 |
| 38 | .003965 | ..... | ..... | .008 | .101 | .00625 | 38 |
| 39 | .003531 | ..... | ..... | .0075 | .099 | .......... | 39 |
| 40 | .003144 | ..... | ..... | .007 | .097 | .......... | 40 |

# WEIGHT IN POUNDS OF A LINEAL FOOT OF ROUND, OCTAGON AND SQUARE STEEL

| Size in In. | Round | Octagon | Square | Size in In. | Round | Octagon | Square |
|---|---|---|---|---|---|---|---|
| 1/16 | .010 | .011 | .013 | 3 1/16 | 25.04 | ...... | 31.89 |
| 1/8 | .042 | .044 | .053 | 3 1/8 | 26.08 | 27.66 | 33.20 |
| 3/16 | .094 | .099 | .120 | 3 3/16 | 27.13 | ...... | 34.55 |
| 1/4 | .168 | .177 | .214 | 3 1/4 | 28.20 | 29.92 | 35.92 |
| 5/16 | .262 | .277 | .334 | 3 5/16 | 29.30 | ...... | 37.31 |
| 3/8 | .378 | .398 | .481 | 3 3/8 | 30.42 | 32.27 | 38.73 |
| 7/16 | .514 | .542 | .655 | 3 7/16 | 31.56 | ...... | 40.18 |
| 1/2 | .671 | .708 | .855 | 3 1/2 | 32.71 | 34.70 | 41.65 |
| 9/16 | .850 | .896 | 1.082 | 3 9/16 | 33.90 | ...... | 43.14 |
| 5/8 | 1.049 | 1.107 | 1.336 | 3 5/8 | 35.09 | 37.23 | 44.68 |
| 11/16 | 1.270 | 1.339 | 1.616 | 3 11/16 | 36.31 | ...... | 46.24 |
| 3/4 | 1.511 | 1.594 | 1.924 | 3 3/4 | 37.56 | 39.84 | 47.82 |
| 13/16 | 1.773 | 1.870 | 2.258 | 3 13/16 | 38.81 | ...... | 49.42 |
| 7/8 | 2.056 | 2.169 | 2.618 | 3 7/8 | 40.10 | 42.54 | 51.05 |
| 15/16 | 2.361 | 2.490 | 3.006 | 3 15/16 | 41.40 | ...... | 52.71 |
| 1 | 2.686 | 2.833 | 3.420 | 4 | 42.73 | 45.33 | 54.40 |
| 1 1/16 | 3.014 | ...... | 3.838 | 4 1/16 | 44.07 | ...... | 56.11 |
| 1 1/8 | 3.379 | 3.585 | 4.303 | 4 1/8 | 45.44 | ...... | 57.85 |
| 1 3/16 | 3.766 | ...... | 4.795 | 4 3/16 | 46.83 | ...... | 59.62 |
| 1 1/4 | 4.173 | 4.427 | 5.312 | 4 1/4 | 48.24 | 51.17 | 61.41 |
| 1 5/16 | 4.600 | ...... | 5.857 | 4 5/16 | 49.66 | ...... | 63.23 |
| 1 3/8 | 5.019 | 5.356 | 6.428 | 4 3/8 | 51.11 | ...... | 65.08 |
| 1 7/16 | 5.518 | ...... | 7.026 | 4 7/16 | 52.58 | ...... | 66.95 |
| 1 1/2 | 6.008 | 6.374 | 7.650 | 4 1/2 | 54.07 | 57.37 | 68.85 |
| 1 9/16 | 6.520 | ...... | 8.301 | 4 9/16 | 55.59 | ...... | 70.78 |
| 1 5/8 | 7.051 | 7.481 | 8.978 | 4 5/8 | 57.12 | ...... | 72.73 |
| 1 11/16 | 7.604 | ...... | 9.682 | 4 11/16 | 58.67 | ...... | 74.70 |
| 1 3/4 | 8.178 | 8.674 | 10.41 | 4 3/4 | 60.25 | 63.92 | 76.71 |
| 1 13/16 | 8.773 | ...... | 11.17 | 4 13/16 | 61.84 | ...... | 78.74 |
| 1 7/8 | 9.388 | 9.960 | 11.95 | 4 7/8 | 63.46 | ...... | 80.81 |
| 1 15/16 | 10.02 | ...... | 12.76 | 4 15/16 | 65.10 | ...... | 82.89 |
| 2 | 10.68 | 11.332 | 13.60 | 5 | 66.76 | 70.83 | 85.00 |
| 2 1/16 | 11.36 | ...... | 14.46 | 5 1/16 | 68.44 | ...... | 87.14 |
| 2 1/8 | 12.06 | 12.793 | 15.35 | 5 1/8 | 70.14 | ...... | 89.30 |
| 2 3/16 | 12.78 | ...... | 16.27 | 5 3/16 | 71.86 | ...... | 91.49 |
| 2 1/4 | 13.52 | 14.343 | 17.22 | 5 1/4 | 73.60 | 78.08 | 93.72 |
| 2 5/16 | 14.28 | ...... | 18.19 | 5 5/16 | 75.37 | ...... | 95.96 |
| 2 3/8 | 15.07 | 15.981 | 19.18 | 5 3/8 | 77.15 | ...... | 98.23 |
| 2 7/16 | 15.86 | ...... | 20.20 | 5 7/16 | 78.95 | ...... | 100.5 |
| 2 1/2 | 16.69 | 17.71 | 21.25 | 5 1/2 | 80.77 | 85.70 | 102.8 |
| 2 9/16 | 17.53 | ...... | 22.33 | 5 9/16 | 82.62 | ...... | 105.2 |
| 2 5/8 | 18.40 | 19.52 | 23.43 | 5 5/8 | 84.49 | ...... | 107.6 |
| 2 11/16 | 19.29 | ...... | 24.56 | 5 11/16 | 86.38 | ...... | 110.0 |
| 2 3/4 | 20.20 | 21.42 | 25.00 | 5 3/4 | 88.29 | 93.67 | 112.4 |
| 2 13/16 | 21.12 | ...... | 26.90 | 5 13/16 | 90.22 | ...... | 114.9 |
| 2 7/8 | 22.07 | 23.41 | 28.10 | 5 7/8 | 92.17 | ...... | 117.4 |
| 2 15/16 | 23.04 | ...... | 29.34 | 5 15/16 | 94.14 | ...... | 119.9 |
| 3 | 24.03 | 25.50 | 30.60 | | | | |

# TABLE

## WATER—SPECIFIC GRAVITY, 1.00
## WEIGHT—CUBIC FOOT, 62½ LBS.

| | Melting Point Degrees F. | Specific Gravity | Weight Cu. Ft. in Lbs. |
|---|---|---|---|
| Tin | 450 | 5.84 | 365 |
| Bismuth | 518 | 9.75 | 609 |
| Cadmium | 610 | 8.64 | 540 |
| Lead | 621 | 11.34 | 708 |
| Zinc | 786 | 7.14 | 446 |
| Antimony | 1166 | 6.62 | 414 |
| Aluminum | 1216 | 2.58 | 161 |
| Silver | 1762 | 10.51 | 658 |
| Gold | 1945 | 19.32 | 1207 |
| Copper | 1981 | 8.91 | 557 |
| Manganese | 2237 | 7.42 | 464 |
| Nickel | 2642 | 8.76 | 547 |
| Cobalt | 2714 | 8.71 | 540 |
| Chromium | 2741 | 6.92 | 432 |
| Vanadium | 3182 | 6.025 | 376 |
| Titanium | 3362 | 3.54 | 221 |
| Tungsten | 5432 | 18.77 | 1173 |
| Iron | 2768 | 7.86 | 491 |
| Mercury | .... | 13.59 | 849 |
| Steel | .... | 7.86 | 489.6 |

## MELTING POINTS

| | | |
|---|---|---|
| Cast Iron | 2210 | deg. Fahr. |
| Wrought Iron | 2912 | " " |
| Steel | 2500 | " " |
| Copper | 2160 | " " |
| Brass | 1900 | " " |
| Lead | 608 | " " |
| Tin | 446 | " " |

# INDEX

ept

RTEEN DAYS

CENTS will be charged for each day
r time.

| | | | |
|---|---|---|---|
| 18 Mr '32 | | | |
| 31 Mr '32 | | | |
| 1 No '35 | | | |
| 22 No '35 | | | |
| 23 Mr '36 | | | |
| 10 Ap '36 | | | |
| [illegible] '36 | | | |
| 30 Oc 37 | | | |
| 12 No '37 | | | |
| 11 Mr 38 | | | |
| 24 Mr '38 | | | |
| 25 Oc 38 | | | |
| 7 No '38 | | | |
| 25 Mr '39 | | | |
| | | | |
| | | | |
| | | | |